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SCIENTIFIC WORK OF THE DEPARTMENT OF AGRICULTURE

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THE ancients saw in the four elements of earth, air, water and fire the basis of being; moderns recognize earth, air, water and sun as the prime requisites for individual and national existence.

The earth is of three parts: the life and growth on the surface; the surface, which sustains life and growth; and the part beneath, which sustains the surface with its life and growth.

The air is of four aspects: it is an extension of the earth; it yields a part of the substance for life and growth on the surface; it is a vehicle for movement of other things; and in its own movement it affects the surface and influences life and growth.

The water is of three forms, liquid, solid and gaseous, and performs five functions: it is a part of the earth; it is jointly with the air an extension of the earth; it yields the chief part of the substance for life and growth; it forms a vehicle for bodies and powers; and in its proper movement it is an effective agency of process, including life and growth.

The sun possesses several powers: it holds the earth in its place; it fixes the succession of days and seasons; it controls the forms of water and the movements of both water and air; it effectuates process, including life and growth; it yields heat, light and actinity; and it stores power on and beneath the surface in fuel to be released through fire.

The power and prosperity of men and nations are measured by knowledge of and control over these natural elements—*i. e.*, human life is, as it were, balanced against and paired with the elementary ma-

terials and forces. In modern times the knowledge is organized in science, and both knowledge and control are gained and promoted by institutions. In leading nations these institutions are partly voluntary associations of individuals, and partly governmental agencies. During recent decades the knowledge is not merely imparted, but measurably gained by educational institutions.

In the United States the earth beneath the surface is investigated by geological surveys, state and federal; the surface is surveyed chiefly by the Geological Survey and Land Office of the Interior Department, the Soil Bureau of the Agricultural Department and the Coast and Geodetic Survey of the Department of Commerce and Labor, with corresponding instrumentalities in some states; and the life and growth on the surface are investigated chiefly by the Forest Service, the Biological Survey and the Bureau of Entomology, so far as natural conditions are concerned, and by the Bureau of Plant Industry, the Bureau of Animal Industry and the Office of Experiment Stations, so far as artificial conditions are concerned, with related instrumentalities in several states. The air in its general aspects and the water in its forms and certain functions are investigated in the Weather Bureau; as vehicles for movement of other things they are investigated in the Geological Survey and some state institutions; in their primary relation to life and growth they are investigated chiefly in the Bureau of Soils, the Office of Experiment Stations and other branches of the Department of Agriculture, and in the Reclamation Service of the Interior Department; and in their immediate relation to life and growth they are investigated chiefly in the Forest Service, the Bureau of Plant Industry, the Bureau of Animal Industry and the Bureau of Fisheries, while the running and standing water in certain applications are considered in the Hydrographic branch of the Geological Survey, the Corps of Engineers of the War Department, the Hydrographic Office of the Navy Department and the Bureau of Corporations in the Department of Commerce and Labor. The general relations of the sun are investigated in the Naval Observatory of the Navy Department, the Coast and Geodetic Survey, the Weather Bureau and the Smithsonian Institution; the relations to the surface and its life and growth are considered in the Bureau of Soils; and the more direct relations to life and growth are considered in the Forest Service, the Bureau of Plant Industry, the Bureau of Animal Industry and other branches of the Department of Agriculture.

So far as the federal government is concerned, the four natural elements of power and prosperity are investigated or considered in themselves or in their applications chiefly in a score of bureaus in five departments, as follows:

Departments	Bureaus
I. War	1. Corps of Engineers
II. Navy	2. Hydrographic Office
	3. Naval Observatory
III. Interior	4. General Land Office
	5. Geological Survey
	6. Reclamation Service
IV. Agriculture	7. Weather Bureau
	8. Bureau of Animal Industry
	9. Bureau of Plant Industry
	10. Forest Service
	11. Bureau of Chemistry
	12. Bureau of Soils
	13. Bureau of Entomology
	14. Biological Survey
	15. Bureau of Statistics
	16. Office of Experiment Stations
	17. Office of Public Roads
V. Commerce and Labor	18. Bureau of Corporations
	19. Census Bureau
	20. Coast and Geodetic Survey
	21. Bureau of Fisheries
	22. Bureau of Standards
	23. Smithsonian Institution

Half of the official bureaus (much more in effective strength) belong to the Department of Agriculture. This department was designed and is maintained expressly to increase and diffuse knowledge concerning the natural sources of power and prosperity; and it is significant that more than three quarters of the investigative work of the federal government has either grown up in or gone over to the youngest two departments of the federal organization, of which the last-formed is essentially commercial.

The federal bureaus are supplemented by corresponding instrumentalities in most of the states, with which there is large and rapidly growing cooperation. The spirit of the work arises chiefly in, and is largely guided by, some score of voluntary associations, with an aggregate membership of several thousand, including most of the investigators for the state and federal agencies. On the whole, the state agencies are of the greater magnitude and the more largely devoted to applications, the federal agencies the more largely devoted to investigation; the latter seem to be growing the more rapidly to meet a strong demand for effective cooperation with states and associations. The most rapid growth is that of the voluntary associations, of which an increasing proportion are devoted to the application rather than to the increase of knowledge; while the growth of the investigative

branches of the educational institutions is proceeding at a geometric rate.

In the strictly scientific aspect, the governmental work pertaining to knowledge and control of the natural elements enters or occupies the fields of astronomy, meteorology (including climatology), geology (including mineralogy and paleontology), biology (including phytology or botany, zoology, entomology, ornithology, ichthyology, etc.), ecology, chemistry and physics—*i. e.*, a large part of the concrete or objective sciences; and it involves applications of all the abstract or subjective sciences, and touches on that series of human sciences with which the others are in a sense paired. In the strictly practical aspect, the work is directed specifically to the earth as affected by air and water and sun in relation to life and growth, including that of men and nations, along lines laid down in the organization of the bureaus and departments; and there is little tendency to follow the lines or occupy the fields of the conventional sciences.

The developments of the last three decades indicate an unforeseen trend: While the subjective sciences are continuing their steady advance as bases of definite knowledge, they are of lessening prominence; the objective sciences are advancing much more rapidly both as applications of the primary sciences and as branches of definite knowledge in themselves; yet the most rapid advance of all is in applications of the objective sciences (with their subjective foundation) to special lines or fields in strict accordance with the established methods and principles. So the sum of definite knowledge is subdivided into ever-multiplying specialties, while the applications become essentially scientific in themselves; observation matures in experimentation, and both purposes and the objects themselves are progressively modified in ways which gradually become utilitarian, *i. e.*, directly tributary to the power and prosperity of men and nations. Meantime the specialties rise to a new plane; in philosophic view (following the suggestions of Sir William Hamilton and Lester F. Ward) they become *conative* or —more abstractly—telic, and reflect that ever-springing desire for betterment expressed by invention; in practical view by the light of current progress they become *directive,* in that the specialist not merely investigates but gradually brings under control and redirects the natural development of the phenomena with which he deals. Now this modern trend is too definite and too consistent to escape thoughtful observers, and has indeed been widely recognized; it may justly be regarded as an expression of inherent tendency and a mark of natural if not inevitable movement. It by no means necessarily indicates a scientific decline, as some apprehend, but rather a normal readjustment of the human mind to the external factors of human existence and welfare; in fact, it but renders progressive and purposive that pre-

vision which is properly extolled as the highest form of science. It seems to define a third stage in the advance of consciously organized knowledge: the first was the subjective stage, marked chiefly by deduction from ill-generalized and often subconscious experiences; the second was the objective or Baconian stage, marked by induction from clearly realized experiences; and the third is the directive (or panurgic) stage, marked by the combined investigation and control of phenomena. The three orders of thought are emotion, cognition, conation; the phases of faculty pass into invention, and are maturing in creation. Knowledge in the first stage was largely accidental; in the second chiefly incidental; in the third it is a means to ends. The progress was and is normal; just as objective science arose largely as applications of subjective principles, so directive science has arisen largely as applications of both subjective and objective knowledge whereby nature is rendered subservient to the power and prosperity of men and nations. The trend does not mean that science is enfeebled or degraded, but only that definite knowledge has been made common knowledge.

In the light of this trend, the rôle of the federal department is clear: Jointly with the strictly scientific associations, it is the custodian of established principles, not merely as the sum of knowledge concerning the natural elements, but as a means of control over these elements. So viewed, the entire department is in proper sense a scientific institution, and both in size and advanced position the foremost in existence. Viewed in the same light, indeed, America is par excellence a nation of science, and this all the more truly because of the general application of definite knowledge to every-day affairs. It may not be denied that the very abundance of knowledge conduces to an ease of life opposing that always rigorous and often unprofitable research required as a basis for continued progress; herein lies the chief need for a national institution of science too firmly founded on established principles to be swayed by passing opinion or popular pressure, yet too near the actualities of national welfare to drift into the realm of unreality; and here has lain the function of the department during a dozen years of wise administration.

In the department the division of the work is both logical and practical, and the methods combine investigation and direction of phenomena: they deal with the substantial basis of individual and national existence—the earth as vitalized and fecundated by the powers of air and water and sun. The primary line of work in logical order pertains to the productive surface as affected by climate and by its own life and growth; the correlative branch of the department is the Bureau of Soils. The second in order pertains to climate; its correlative is the Weather Bureau. The third pertains to the flora, native and

cultivated; the correlative branches are the Forest Service and the Bureau of Plant Industry. The fourth pertains to the fauna, both wild and domesticated, correlative respectively with the Biological Survey and the Bureau of Animal Industry, together with the ancillary insect life, correlative with the Bureau of Entomology. Adjunct lines of work pertain to certain molecular relations, treated in the Bureau of Chemistry and the Office of Public Roads; to quantitative or economic relations, treated in the Bureau of Statistics; and to ecologic relations, treated largely in the Office of Experiment Stations. In each line the primary purpose is to discover facts and relations connected with development or growth; the secondary purpose is to redirect and control the course of natural development, and the ultimate purpose is to progressively artificialize the earth with its life and growth for the benefit of men and nations. In every line the constant effort is to increase the efficiency of the better and to either improve or eliminate the worse, and this in the light of all knowledge and the exercise of all natural and human power.

The immediate basis of life and growth on the earth is the soil; it yields substance for the flora, which in turn sustains the fauna. At the same time it is itself derived from cruder earth-matter largely by the action of plants and animals, and its chief elements of fertility (such as nitrates and potassates and phosphates) are organic derivatives. Thus the primary law of the soil is cumulative enrichment through interaction with floras and faunas; to this law it has normally conformed throughout the geologic ages; and the primary duty of the soil specialist is to accelerate and intensify the natural progress, and thereby to increase soil efficiency. Now the efficiency of soils depends wholly on the associated water and air (unless indeed these be considered integral parts of the soil), of which the former especially maintains a sort of circulation, dissolving earth-salts, conveying plant-food into and through the circulatory systems of the living and growing plants, and carrying the acids of growth and decay back to the earth-matter to hasten its solution—so that the active agency or principle of soil efficiency is the soil water. The normal processes are sometimes interrupted or impeded by abnormalities: Certain organic derivatives are excretory, and poisonous to the plants yielding them and sometimes to others; climatal and other natural conditions in connection with cultural changes sometimes disturb the circulation of soil water, or permit surface erosion and leaching to impoverish or even completely remove the soil; and unsuitable plants sometimes gain such foothold as to exclude organisms better adapted to normal enrichment of the soil. Accordingly, the soil work comprises (1) examination and classification of soils with respect to materials and potentialities; (2) determination of the soil water and its movements

and interactions; (3) discovery of normal tendencies toward enrichment, physical, chemical and bacterial; (4) detection and elimination of abnormal tendencies; and (5) prescription of treatment required for regulating and intensifying the natural processes and thereby increasing efficiency. The researches render it clear that the soil is the product of uncounted eons of interaction between the organic and inorganic; that the slow production of a soil is a process no less definite than the quicker production of a crop or a flora; that the process may be brought wholly under human control; and that in view of increasing population, the welfare of men and nations henceforth must depend on the care and intelligence devoted to the maintenance and improvement of this gift of the ages.

The controlling condition of life and growth on the soil is climate, especially that ever-varying temperature and moisture and air movement forming weather. The first need concerning weather is foreknowledge (or prevision) definite enough to permit prediction; and while the earlier investigations were directed to this end, they necessarily included examination and classification of the atmosphere with its aqueous vapor, and determinations of temperature, rainfall, vapor-tension and other factors. Herein the usual course of progress was reversed; commonly discovery of principles precedes both appreciation and utilization of phenomena; but in weather work the need inspired search for the principles—*i. e.*, the ends led the means. With like contrariety, the effort for control was directed not so much to the natural factors of weather as to the movements of men and other organisms in adjustment thereto—indeed even yet the wind bloweth as it listeth, while men merely prepare to meet or escape its force. Still, as the work progressed, both the constants and the caprices of the air with its associated water were measured in such manner as not only to permit prevision within reasonable limits, and thereby afford practically useful weather prediction, but to yield definite knowledge of a use extending far beyond the primary need. Thus, it has become clear that in so far as life and growth are concerned the rôle of the aqueous vapor is paramount; plants absorb and transpire water to an amount usually exceeding many times their own volume during each season; and their action affects not only the circulation of soil water air below the surface, but the humidity of the air and the circulation of both air and water about and above them. Again it appears that the average rainfall of the United States is less than half that required for full productivity in native and cultivated organisms; yet that some 90 per cent. of the rain-water gathering into streams is wasted in floods which annually wreak damage to an amount exceeding the estimated cost of flood prevention, and this despite a large saving of life and property by reason of flood warnings issued by the Weather

Bureau. So the measurements are preparing the way for such control of the rain that this gift of the heavens will be made an unmixed benefit instead of a partial evil. Of the entire rainfall, only about a third flows through rivers into the sea (chiefly in floods), while it is estimated that fully half is evaporated, thereby returning to the air to affect the weather and temper the climate; and measurements of evaporation have begun, and will doubtless open means of exercising some control over the water in the air, no less than that on the surface and within the soil. Meantime it is estimated that less than a sixth of the mean annual rainfall is actually utilized in life and growth and other useful processes connected with the soil and its productions; and it is becoming clear that larger and better uses of the elemental water are possible through progressive redirection of the natural processes and powers. In the beginning, men bowed to the storm and fled the flood; later they predicted in order to seek shelter before the storm arrived; now they seek control at least of the storm waters in order that their volume and strength may be directed to welfare.

The four elements interact through organisms, of which the substance is mainly from the soil and water and their products; their circulatory medium and chief constituent is water, their force is from the sun, and their functions are maintained by air. During the ages the native flora adjusted itself to soil and earth-shaping agencies so closely that each type produced a surface to fit its needs—forests developing deep and friable soils and steeper slopes, grasses developing thinner soils and flatter slopes, and mosses producing spongy soils lining basins, each according to its kind and its capacity as conditioned by climate. A quarter of the area of the United States was too arid to sustain a full floral mantle, a third was wooded and more than a third was grassed when settlement began; for wherever the water supply suffices, vitality overspreads the surface and dominates the inorganic earth. Without water, vitality fails; there is neither assimilation nor germination, nor yet metabolism, in the absence of liquid, while transpiration and respiration depend largely on the passage of water from liquid to vapor. With water, the primarily organic circulation extends from the plant to the soil below and the air above and passes into still more complicated interrelations in animal bodies; and the locus of most effective energizing on the planet is the infinitely complex surface—the soil with its extensions in stem, leaf, flower, fruit and other organic bodies—at which water is continually passing from one form to another, absorbing or yielding latent heat, and mechanically interacting with the sun in seizing and storing and transferring molecular action. This is the complex in which vitality attains dominance over lower nature; and through it investigators are attaining control over the vital powers for the welfare of men and nations.

Thus, the normal circulation is notably complete in woodlands, and is notably deranged by deforestation; when the trees are felled and not replaced by other cover transpiration ceases, the air dries so that seeds and seedlings may wither, and the soil-water level lowers; the duff is desiccated and wind-blown, leaving the previously porous soil to harden and bake; and as storms arise the raindrops are no longer dashed into spray by twigs and foliage and conveyed gently through litter and natural mulch into a friable soil of enormous capacity for feeding springs and brooks, but beat still harder the indurated ground—and then gather in surface rivulets and rills running swiftly down the slopes, eroding and gullying the soil on the way, clogging valleys with the débris, and rushing as turbid torrents into the sea with little benefit and large injury on their way. The Forest Service was created largely to counteract reckless deforestation and maintain the timber supply in certain sections of the country; yet it has grown into administration of 170,000,000 acres of woodland, while its highest duty has come to be that of acquiring and diffusing definite knowledge and directing specific effort toward control over the powers of nature in such manner as to protect the water supply and regulate that balance of industries connected with woods and waters required for the common prosperity. The investigations extend into vegetal physiology and the vital mechanism of the individual seed or slip or tree no less than into the collective action and relations of the forest considered as a unit, and pass over into both natural and artificial production. The aim is increased efficiency of both individual trees and forests; the end is higher national efficiency; the means, progressive control over natural powers through definite knowledge and purposive application.

Over millions of acres of grass-lands and former woodlands, the native flora is wholly or partly replaced by crop plants, and it is the manifest destiny of all available lands to be consecrated wholly to production or inhabitation or other human uses. In prehistoric times men began to subsist on the products of the soil, and through unwitting selection improved wheat and rye and barley and rice in the old world and corn and beans in the new; and during the historical period the improvement of the useful types and the replacement of useless or noxious types were continued under the guidance of increasing knowledge. Since the Department of Agriculture was created—and largely through its agency—the sum of human knowledge relating to crop plants and their efficiency in this country has more than doubled; and now the utility of plants is traced directly to individual vitality—to the specific factors of cell function and reaction to stimuli and hereditary tendency combining with capacity for transpiration to determine rate and limit of growth—which is itself measurably susceptible of modification. In this way the Bureau of Plant Industry is steadily

gaining control over the powers of nature through redirection of the vital energy of the plants along more useful lines directed toward ends of human welfare. The control is collective no less than individual: Native plants vary, and the fitter survive; Darwin noted the increasing variation of plants under domestication, and thereby detected a natural law of increasing plasticity of types; and now under the law variability is accelerated and the fitter forms are selected and multiplied, so that the efficiency of crops is increased. Under natural conditions, plants spread slowly and with the tediousness of unlimited time adjusted themselves to particular soils and climates; with settlement, pioneers introduced new plants which were often found fitter than those of native growth; now the plains and mountains of the world are scoured to find types adapted to less productive districts, and thereby the efficiency of entire floras is increasing. And the end is not yet. Agriculture began with the accidental dropping of seeds in accidentally fertilized spots; in time the middens were expanded into gardens and these into fields; and now plain common sense and reasonable foresight look to the extension of planting and cultivating and cropping over all the humid country and so far into the arid lands as complete utilization of the scant waters will permit. Our 3,000,000 square miles or 2,000,000,000 acres, now sustain about 90,000,000 inhabitants, or 30 per square mile, and our exports of food-stuffs are falling off; within 65 years the population will doubtless double, and by the end of the century it will treble—yet the 250,000,000 mouths must not only be fully fed, but a margin of food-stuffs for export must be left over if prosperity is to persist. To attain this end, plant efficiency must be increased; not only must two heads of wheat be made to grow where a blade of grass grew before, but each square rod must be made to yield a bushel instead of a peck of grain, and more nutritious grains must be invented and created and kept employed in converting the crude ore of lower nature into the coin of individual and national welfare. It is no longer enough to know the plants and vital processes of nature; it is becoming necessary so to redirect nature as to produce more efficient plants by improving the vital processes—and this is a current duty of the Bureau of Plant Industry.

Even more plastic than plants are the faunal forms, both wild and domesticated; and before history began, kine and swine and sheep and fowls were so far artificialized by selection and breeding that the ancestral forms were obscured. It is the business of the Biological Survey and Bureau of Entomology to investigate the native fauna and classify the forms, technically into orders and genera and species and practically into useful and injurious—and then to perpetuate the good and reform or extirpate the evil, operating largely through the vital forces of the organisms themselves; and the world is scoured for

information as to species and stocks of mammals and birds and fishes, for insect mates to symbiotic plants and insect enemies to noxious organisms, and even for germs and cultures affecting the course of organic progress. Meantime the Bureau of Animal Industry is not only acquiring and diffusing definite knowledge concerning stocks and breeding and feeding, but is importing and acclimating and crossing the animals with the view of supplying each section with forms adapted to its particular conditions and requirements. Thereby the domesticated animals are modified and adjusted to a complex industrial mechanism, each yielding flesh or milk or leather or textile or eggs or feathers or labor after its kind in connection with the human purpose; and if the natural powers are feeble or aimless, they are so redirected and intensified as to increase the efficiency of the organisms in promoting the welfare of men and nations.

Broadly, the functions of the other Federal Departments pertain chiefly to relations among men, those of the Department of Agriculture chiefly to the relations between men and nature. Its primary purpose, both logical and legal, is to increase and diffuse knowledge concerning those fundamentals of human power and prosperity residing in the soil and its products. In carrying out this purpose, it necessarily assimilates and promotes that consciously organized and definite knowledge pertaining to nature which constitutes both the subject-matter and the object-matter of science; and with its growth it has been called on to make all manner of applications, from the extirpation of insect pests to the protection of the purity of foods and medicines for men and the making of roads for moving the produce of the soil. Its final function, which has arisen and taken form with its growth, is the redirection of natural processes and powers along lines which are not only previsedd, but clearly preconceived in relation to ends—and hence are practical. In performing this function, it deals constantly with the four primal elements in their relation to man; beginning with the earth, it progressively increases the efficiency of soils and plants and animals; and through this element it utilizes and so gains partial control over the air, the water and the power of the sun—and the measure of the efficiency is human power and prosperity.

Thus far the relations chiefly considered in the Department of Agriculture have been those of nature, and of men to nature, adapted to increasing the efficiency of nature for human ends; there has been little effort to apply the natural powers to men or to increase their efficiency except by arming them with better knowledge. The time for directly increasing human efficiency by intensifying human power has hardly come; yet it may easily be descried as the next stage in the development of relations between men and nature.

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INSTINCT AND INTELLIGENCE IN BIRDS.—I

By Professor FRANCIS H. HERRICK
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I

THERE is no doubt, as Jevons has remarked, that if ants had better brains than men, they would either destroy the human race or reduce it to a state of slavery, but these busy little workers offer no black or yellow peril to mankind, for they are all headed in the wrong direction. In the social hymenoptera nature seems to have done her best with a nervous system built upon the simple arthropod plan, in which segmentation, begun at a still lower level in the animal scale, is the dominant character of its structure, and instinct the ruling method of its response.

The vertebrate, on the other hand, has a nervous system of not only a higher but of a very different order, in which response has left the beaten track of instinct, and become more and more molded upon experience. Classification of these higher types on the ground of anatomy agrees plainly with classification on the score of behavior, and this agreement is based upon the structure of the nervous system, the chief function of which is to order and control response.

It is to the evolution of the cerebrum that the vertebrate owes its powers of rational response, and the higher we rise in the scale of vertebrate ascent from the bony fishes, the greater the development of the cerebral cortex, and the keener the mind of the animal, or the greater its power to subdue its hereditary tendencies, to make its acts accord with the results of experience, or the needs of the moment, and to anticipate the future.

The instincts used to be regarded as immutable, and are now often spoken of as "stereotyped," but in the use of the latter term there is need of frequent qualification, and habits even by repetition become automatic. The mechanical operation of habits, which is universally recognized, has given rise to the idea that acquired automatism may appear in the descendants as inherited or congenital automatism, that instincts are inherited habits and merely illustrate "lapsed intelligence," or habits from which the intellectual processes through which they were originally acquired have "lapsed" or disappeared. The confusion and absurdity with which this view can invest a difficult question is well illustrated by Eimer's[1] attempt to explain the parasitic instinct of the European cuckoo, which regularly lays its eggs in other birds' nests.

[1] Eimer, Theodor G. H., "Organic Evolution," p. 256, London, 1890.

Eimer is convinced that the little foundling of a cuckoo has so good a memory of its foster-parents and of the nest in which it was reared, that it is able to make a proper choice of both when it comes to lay its eggs in after life, and further that the experiences of its early youth have "at last become instinctive by inheritance." It can not build a nest because it has never learned how, and if it never builds it can not of course transmit the instinct of nidification. When its original progenitors adopted their piratical methods, they did so with their eyes open, for they acted from "reflection and with design." The male cuckoos are dissolute vagabonds and the females as bad or worse, for they wander about not so much to find nests to steal, as to appease "their insatiable sexual desires."

That some instincts, in both arthropods and vertebrates, have not perceptibly changed from age to age is not to be doubted. As Sidney Smith observed, the wonderful instincts of animals seem to have been given them for the preservation of their species, and that without them they would have long ago perished. He says:

> The bee that understands one particular kind of architecture so well, once out of his own special line of business, that of making honey, is as stupid as a pebble stone, and with all his talents only exists that we may eat his labours, while poets sing of them; or he constructs his boasted edifice for an egg of which he knows neither the meaning nor the object, to produce a grub of which he can form no possible conception; whereas man knows the beauty of every brick he lays, or tower that he builds. The bee now builds just as he built in the days of Homer; the bear is just as ignorant of good manners as he was two thousand years ago, or ages ago; the baboon still as unable to read and write as persons of honour or quality were in the days of Queen Elizabeth; but there is no progress among the three B's, whereas now among all classes of men those who can read and write are to be counted by the millions.

We might add that the European cuckoo seems to have been no less adept in stealing nests in the time of Aristotle than it is at this day, and that even among the most rational, adaptable, and most plastic of living beings, in his humblest estate, progress has been but little greater.

II

In some of the fishes, in reptiles, and more particularly in the birds, we can discern the early if often halting steps of that intelligence which in the highest of the primates was destined to turn the world upside down. We can not attempt to specify with any detail the structure of the avian brain, nor would it be of any use to do so, unless we could award the proper functions to its several parts. While this can not now be done, psychology has already learned some valuable lessons from anatomy, at the hands of such a master as Edinger, and is destined to learn many more. Without doubt, in the future, knowledge of the brain of the fish, of the reptile and of the bird will serve as primers for the understanding of the cerebral cortex.

Edinger[2] has shown that to the primitive division of the brain of the vertebrate (or the paleencephalon), which is the bearer of the reflexes and the instincts, there has been gradually added with peculiar adjustments a newer division (the neencephalon), which corresponds to the cerebrum, in which alone is centered the power of association, and of forming memory images. In proportion as the cerebral cortex increases, the primitive brain recedes, while in a corresponding ratio intelligence rises, and purblind instinct wanes.

A very interesting fact for us, as Edinger has further shown, is that while the cerebral cortex of the bird is more highly developed than in reptiles, the far greater bulk of the brain is mainly due to an enlargement of the primitive division, the parts of which reach a size and proportion nowhere else seen, while at the same time they are very generally connected with the cerebrum. From these facts alone we are warranted to infer that while birds are intelligent and able to form associations of some sort freely, they must be animals in which the instincts are developed to an extraordinary degree of perfection, comparable in large measure with those of the social insects. All this is amply proved by their behavior, and in describing the activities of birds it seems best to discriminate as sharply as possible their instinctive activities from the operations of intelligence, assuming, until the contrary is proved, that their reflexes and instincts pertain exclusively to the primitive division of the brain, as already stated, while the power of association is lodged in the cerebrum alone.

Not only does the bird's brain possess great basal ganglia of which the huge optic lobes are most prominent, but a large cerebellum, and very diminutive, possibly rudimentary olfactory lobes. These facts find their clear counterpart in behavior. Large optic nerves, optic tracts and lobes, are to be expected in animals like the birds, which possess the keenest eyes of any vertebrates known, and which depend so largely upon vision for finding their food and for detecting their enemies and their friends.

The wonderful powers of flight, possessed by birds as a class, may not only be long sustained, as in the golden plover which is supposed to make the journey from Nova Scotia to the West Indies, a distance of 1,700 miles, in a single flight, but is often so rapid that fatal results would follow were the control of direction less precise. Their movements clearly demand an organ for the most perfect coordination of their skeletal muscles, and such is undoubtedly found in their large cerebellum, the action of which is purely reflex. Thus swallows are often seen to enter a barn, where they have their nests, at a perilously rapid rate, through cracks or holes, barely large enough to admit their

[2] Edinger, Ludwig, "The Relations of Comparative Anatomy to Comparative Psychology" (translated by H. W. Rand), *Journ. of Comp. Neurology and Psychology*, Vol. XVIII., No. 5, 1908.

bodies. Under such circumstances a slight error in muscular coordination would be fatal, and I have found fully grown and presumably young birds lying dead beneath such openings, where it was evident from the wounds received that death was accidental, and due to lack of precision in flight. The common swift also moves with astounding rapidity, as if heedless of consequences, but usually avoids every obstacle in its path, even in waning light. It gathers the materials for its twig nests while darting through the branches of a tree, with barely a pause, as it bends to seize in its bill the twig, which is snapped off by the momentum thus gained. Yet mistakes are sometimes made even by the master swift, and I have known a case where a bird of this kind, and possibly a young one, impaled itself on the sharp point of a lightning rod.

The toothed birds of the Cretaceous period, of which *Hesperornis* is a type, are known to have possessed a brain more nearly approaching that of the reptiles in form, with large olfactory lobes. It thus seems evident that the olfactory sense has lapsed and become rudimentary in most modern birds. Edinger, however, maintains that since birds possess true, though small olfactory lobes, they must smell, but behavior seems to afford the better criterion in such a case. Whatever the advocates of the eye and the nose may have to offer in the future in regard to the habits of buzzards and other old and new world scavengers, repeated experiment has convinced me that the common birds of the country, can not detect their young at a distance of three feet, unless they either see or hear them. In fact, all of the close-at-hand, " as-near-as-you-hold-a-book-to-read " observation, carried on for the past ten years, some of which is to follow, has been conditioned upon the extremely feeble development, if not total lack of this sense.

III

The instincts of birds may be classed in a general way as (1) continuous instincts, which are needed for the preservation of the individual, such as preying, flight, concealment and fear, however subject to modification through experience, and (2) the cyclical instincts, which are necessary for the preservation of the race.

By cyclical instincts we mean those discontinuous, recurrent tendencies to action which are serial in form, and which together characterize the reproductive cycle. They may be called, with some allowance, the parental instincts, it being understood that this epithet is used in a descriptive sense, and that there is no one kind of reaction to which the term is specially applied. These instincts recur with clock-like regularity in the spring and summer in the northern hemisphere, and are subject to repetition, more or less complete, within the breeding season of certain species or individuals.

For convenience the breeding cycle may be described as made up of a series of terms as follows:

1. Migration to Breeding Area;
2. Courtship and Mating;
3. Nest Building;
4. Laying Eggs in Nest;
5. Incubation and Care of Eggs;
6. Care of Young in Nest;
7. Care of Young out of Nest;
8. Migration to Feeding Area.

Beginning at 2, 3 or 4, according to circumstances, the cycle may be repeated one or more times within the breeding season, or a new cycle may be begun, and stayed at any step from nest-building to laying of the eggs. Again, an entire cycle may be brought near the close, and then scamped, the young being left to die.

The reproductive cycle may be graphically represented by a number of tangent circles, each of which stands for a distinct sphere of influence or for a subordinate series of related impulses. It is evident that these serial instincts must be in relatively perfect harmony, or if regular perturbations occur, new and permanent adjustments must be forthcoming to meet them, if the species is to continue to exist. One act or series of related acts must be performed in preparation for that which follows. The nest must "anticipate" the eggs, and not the egg the nest. Upon the whole the serial instincts of birds are well attuned, yet disturbances more frequently occur than is commonly supposed, and by conditions of this kind much that is anomalous or eccentric in the behavior of birds can be explained, as we shall later see.

The cyclical instincts are profoundly affected by fear at terms 3 and 4, and the whole fabric of instinctive life is subject at nearly every step to the modifying influence of intelligence. In the reproductive cycle, as elsewhere, the same struggle is seen between competing or conflicting instincts, especially where attunement is imperfect, leading now to a fuller expression, and now to a total neglect of the usual activities. The number of terms, of which eight are given above, is unimportant, so long as it is recognized that they occur in serial form, and that many activities such as brooding, and feeding the young, are recurrent.

Certain subordinate instincts rise and wane during the reproductive cycle, thus adding to the complex of behavior. Song, which is primarily instinctive, often begins in the male during the time of mating, but that it is not wholly dependent upon the reproductive function is proved by the fact that it is not always coincident with the breeding period. Thus, it was shown as early as 1834 by Blackwall, that singing may cease before the nest is built, or last long after the young have flown. Again the fighting instinct usually emerges early (at 2 or 3) and is long continued. In that inbred pugnacity, which characterizes the breeding season of birds and higher animals, we possess the key, as I believe, to the origin of the instinct of incubation. According to this

FIG. 1. FEMALE ROBIN IN A PARTIAL SHIELDING ATTITUDE, on a hot day.

FIG. 2. KINGBIRD IN TYPICAL SHIELDING POSITION, standing over young, with wings partly spread, and feathers partly erect.

idea the guarding evoked by the fighting instinct, and supplemented by the instinct to cover or hide the eggs, is responsible for the incubating instinct, which in the modern birds is usually strongest in the female, but is not always confined to that sex.

The possible stages in the evolution of the instinct of incubation in the reptilian ancestors of birds, upon the basis of selection, may have been as follows: first burying the eggs, like the turtle; secondly, burying or concealing the eggs and guarding them, the necessary warmth being furnished by decomposing vegetable débris, as in the alligator, and not directly from the sun; thirdly, laying the eggs and sitting over them to conceal as well as to protect them,[3] in a secluded place, the necessary heat now being furnished by the body of the parent. In the first instance the eggs may not have been concealed, but it seems probable that the instincts of both concealment and pugnacity were contemporaneous, as they were certainly very early in origin.

With incubation is associated a variety of interesting and important instinctive activities, such as rolling the eggs with the bill upon entering the nest, as may be observed in the great herring gull, placing them in position, or stirring them up with the feet, to be seen also in the gull, the domestic fowls and in a great number of wild species; covering the eggs when leaving them, a common practise of the grebes, or standing over the nest and with spread wings shielding the eggs from intense heat, as I have once observed in the least flycatcher; cleaning the nest by removal of broken or addled eggs, which must frequently occur in many species, which I was once fortunate enough to witness from the tent in the least tern on one of the Weepecket islands in Buzzard's Bay. On a very hot day in July one of the eggs, during the absence of the birds, exploded with the report of a pop-gun and blew a small hole in one side. Upon her return this resourceful bird inspected the nest for a moment, and bending down, inserted her lower mandible in the blow-hole; then lifting the heavy egg in her bill, she bore it off slowly over the water and dropped it in the sea. At her next visit every particle which might defile the nest was gathered up and carried away.

The care of the young in the nest (6) embraces a number of fairly well stereotyped, recurrent acts such as (*a*) the search after prey, its capture and subsequent treatment; thus some birds regularly mince the prey or beat it into a pulp, while others, like the little house wrens, bring moths and various insects to their nest with wings and legs, or with wings alone, removed. Kingbirds have been seen to bruise unruly insects between their bills while at the nest, one assisting the other, and have been photographed in the act, while it is not an unusual sight to

[3] It is evident that pythons, which lie upon their eggs, secure in this way both protection and concealment for their offspring.

see an insect which has been inserted in the mouth of a nestling, withdrawn, minced with the bill, and offered again. When behavior is free the return to the nest (*b*), is prompt and direct, but birds will frequently pause at some point near by and look about as if for assurance. The black-billed cuckoo if timid or suspicious, will sometimes stand on such a perch with insect in bill for five or ten minutes without uttering a sound, but occasionally pumping its tail, stretching its head and looking cautiously around, or again it will remain perfectly quiet like a statuette. The actual path which is now taken to the nest is eventually

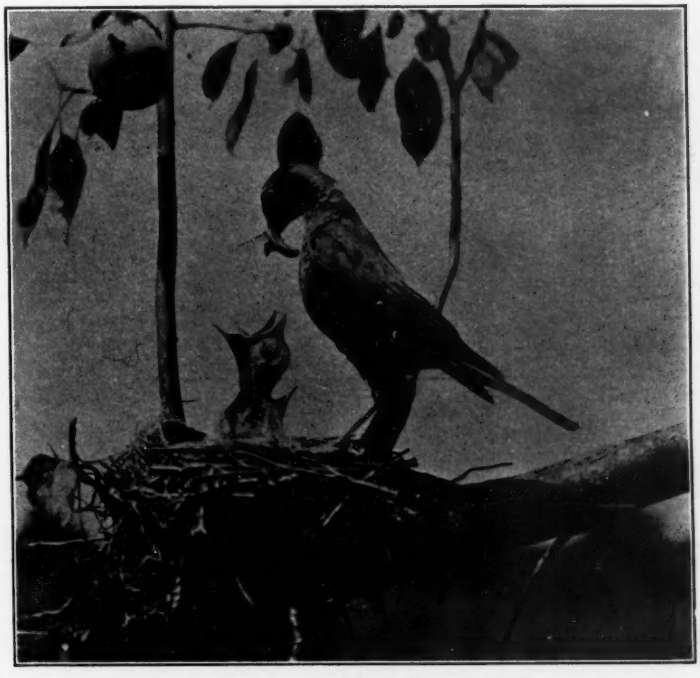

FIG. 3. ROBIN "TAKING AIM." After photograph by John B. Parker.

determined by habit. The bird flies to a certain branch, grasps certain twigs, before it finally lands on a certain part of the nest itself. Then usually follows a pause as the bird straightens up and stands over her young. If the mate is brooding, as is likely to be the case in bad weather, a call-note is sometimes given by the visiting bird, when the sitter promptly retires. This note is often heard in the absence of the mate, when it serves as a stimulus to the young. Further the sitter, if a cuckoo, always detects the approach of the visiting bird by hearing, if not by sight, so that the whole family is practically never seen together at the nest, contrary to what often happens with gulls, robins, cedar-birds, kingbirds, or some of the warblers. The young detect the approach of the parent by sight or sound, or by the vibration imparted

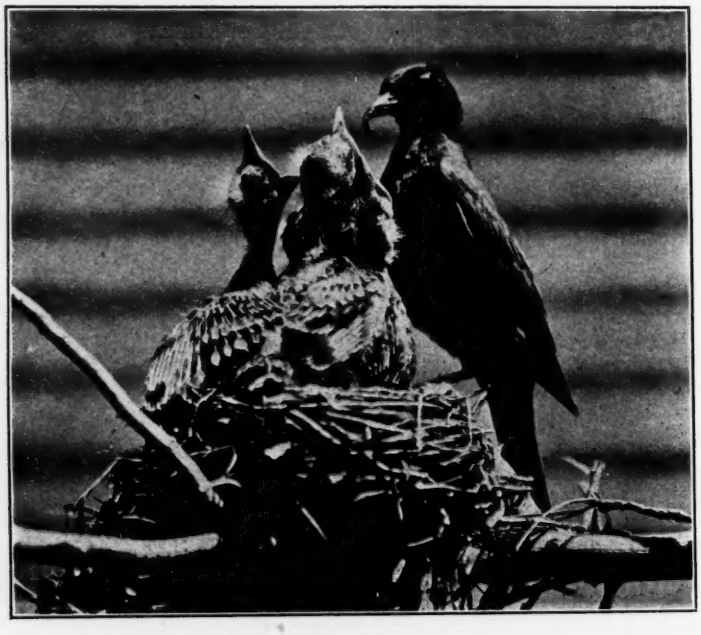

FIG. 4. ROBIN IN SIMILAR PHASE OF THE FEEDING PROCESS, but with young at later stage of nest-life. Illustrating type of direct feeding, where one bird only is commonly served at each visit. After photograph by John B. Parker.

to the nest itself or to the branches about it, and if hungry respond with the greatest vigor and excitement. When response is dull or lagging, however, the parent usually utters a call-stimulus, a peculiar note, of low pitch, and varying in quality in different species; if this should pass unheeded, it may become very shrill and rasping.

Feeding the young in birds is either (*a*) a passive process characteristic of certain precocious birds like gulls, in which the food is regurgitated from stomach and gullet upon the ground (Figs. 11 and 12) or (*b*) it is very direct, in which case the food is generally inserted into the throat (Figs. 7 and 8), the common practise of altricious birds. In the first instance, a young gull, the hatching of which was witnessed, received its first food, consisting of small lumps of predigested fish, when two hours old, and at the nest. Although this food was placed within easy reach of the chick, and was even picked up and held before its bill, no other encouragement was given and it was never inserted into mouth or throat.

The essence of the direct method of feeding is to test the swallowing reflex of the nestling. The food may be carried in gullet or stomach, and regurgitated from one or both to the mouth, before service, or it may be carried visibly in the bill, as in robins and passerine birds generally, and fed direct from bill to throat, one bird only, as a rule, being fed at each visit of the parent. Thus cedar-birds regurgitate mainly

from the gullet (Figs. 5 and 6), and the berries or insects come out entire, but covered with slime, more than one bird being quickly served at each visit. In woodpeckers and goldfinches, which are fed at longer intervals, the food comes up in the form of a "pap" or "mash," probably from the stomach in part, to judge from the outlines of the neck, and all are fed rapidly as before.

The nestling gives the "opening" response, and shows its "food-target," while the parent, if a robin, vireo or one of many altrices, "aims" (Figs. 3 and 4) and inserts the food deep into the throat, presses it gently down, and watches it, watches, we may say for the swallowing reflex of the throat. If not quickly taken, the food is whisked out and passed around, one bird after another being tried in succession, until a throat with the proper reaction-time is found. There is commonly no distribution of food among the offspring, on any other basis than this. The youngster which can react most promptly, is thus favored, because he holds up most of the food; accordingly he grows fastest, and outstrips his competing nest-mates. The young cowbird drives the children of its nurse quickly to the wall because it reacts with greater vigor from the first, and interferes with any proper distribution of the food. It is not uncommon to see the same bird, usually the larger and stronger one, fed two or three times in succession, but the full gullet checks the swallowing reflex, and thus automatically applies a brake to the greediness of a nestling, which might otherwise gorge itself to suffocation.

FIG. 5. CEDARBIRD AT NEST WITH FULL GULLET. First stage in reaction of young.

It must be noticed, however, that the goldfinches, referred to above, afford a partial exception to this rule. The young at the two nests of this species, which I have studied, were invariably fed with a white or greenish, sometimes frothy, semi-liquid seed-pap, each bird getting some, and at times from two to four doses, at each visit. Such birds react with great uniformity, and are remarkably uniform in their growth (Figs. 9 and 10). The feeding is extremely rapid, and so little of the pap is ever lost, that on only one or two occasions have I been able to get a drop of it for examination. It consisted of very small, immature seeds of some plant like the bull thistle or mullein.

FIG. 6. CEDARBIRD BEGINNING TO REGURGITATE. Final stage in reaction (opening response) of young. Feeding is by regurgitation and direct, several being fed at each visit.

While all the common passerine birds of the country feed their young in the way described, at nests of the cuckoos a most singular and remarkable performance may be witnessed, for these interesting birds not only test the throats of their clamoring brood in the usual way, but practise what may be called *mouth-feeding* also. Thus we have repeatedly seen the female black-billed cuckoo bring to her nest caterpillars, or larvæ of some of the larger moths, from two or three inches long, already limp, and pinched at a point just behind the head. At the food response or opening reaction, she would lay the insect in the mouth of the young one, and without relaxing her grip, hold it there, mother and child standing immovable from two to five minutes by

the watch, until suddenly the machinery would begin to work, and the long body of the larva would slide down the throat of the nestling, as if greased. The insect was laid crosswise between the mandibles, which closed upon it, but not always with sufficient force to hold it, for when the parent relaxed her grip, on more than one occasion it fell on the nest, and was picked up and offered again in the same manner. During this period of suspense, the mouth of the little bird would water copiously, and now and then the insect would be moved slightly by the parent, or withdrawn and returned to the same bird.

When the feeding is over, inspection (*e*) follows with clock-like regularity, provided always that behavior is free, and with head inclined to be prone, the parent inspects young and nest, with a view of cleaning them (*f*) which means the removal of the excreta, or of any particles of food which may have escaped the young. The cleaning instinct is very wide-spread among the whole class of birds, which from the human standpoint are probably the cleanest of all vertebrates which live out of water.

The study of the cleaning instinct in birds offers many surprises, and shows us plainly that besides the question of sanitation, which might be assumed to be of paramount importance, there is the element of concealment, which in the smaller and more timid species really counts for more, while of lesser significance is the value of the excreta as food for the adult. A young bird ordinarily mutes shortly after the food taken reaches its stomach, or at least after it is swallowed, and in so doing instinctively turns so that the raised hinder end of its body is directed toward the margin of the nest. Consequently the sac, when allowed to fall, usually lands on the nest-rim, when it does not reach the ground. The excreta in cuckoos, and in most passerine birds, to mention but two prominent orders, are in the form of tenacious, mucous sacs, which are snapped up as they leave the cloaca of the nestling, and are either eaten or removed (Fig. 14). This sac resembles a rubber water bottle with thin transparent walls closed on all sides, which can be rolled or picked up without soiling bill or fingers. Digestion is very rapid in nestlings, and remains of insects have been found in a sac from a black-billed cuckoo but four hours old. But while the digestive process is rapid, it is often very imperfect, and compact fruits like the blueberry will sometimes pass the alimentary tract without change. This in part explains the use of the excreta as food, and suggests that whether they are to be eaten or removed it is only a question of hunger at the moment. Robins, when they do not devour the sacs outright, carry them away, flying low with depressed head, and drop them a few rods from the nest, but are sometimes seen to peck at them after reaching the ground. In some species, like cedar-birds, and again in certain individuals only, the excreta are more regularly and continu-

ously eaten than in others, and there can be no doubt that habit often decides the question. Fear, however, is another variable to be reckoned with, for if this sense is aroused at the moment the bird has seized a sac to bear it from the nest, it seems to be eaten as the easiest solution of the difficulty. Perhaps a counterpart of this sort of behavior is seen when a bird with food in bill suddenly encounters the naturalist, or any other fearsome object, for it immediately sounds the alarm, and promptly swallows the insect. When more than one sac is taken, all are usually eaten. It is not an uncommon sight to see a bird walk around the nest and take a "white marble" from three birds in succession, for in muting, a bird is sometimes followed by one or more of its mates, and anything which soils the nest is quickly removed. More than once I have seen a sac, which had dropped from a nestling snapped up by the old bird before it had fallen two feet in the air; and birds will even descend to the ground for the sacs, if necessary. Twice I have seen the male chestnut-sided warbler take a sac to carry it off, and the hungry female snatch it from him, devour it and settle down to brood.

Removing the excreta piecemeal and dropping them at a safe distance is the common instinctive method not only of ensuring the sanitary condition of the nest itself, but, what is even more important, of keeping the grass and leaves below free from any sign which might betray them to an enemy. Bluebirds and redwing blackbirds often carry the sacs a long distance before letting them fall. Crow blackbirds sometimes drop them in the water, and house wrens and nuthatches implant them on the bark of trees. This instinct, like so many others in the reproductive cycle, after running its course, begins to wane, and even before the close of nest-life, so that it is not correct to say that the nest of the cuckoo or the flicker is always sweet and clean. I examined a hoopoe's nest in upper Egypt, near Luxor, on March 26, which was filthy in the extreme, but hardly worse from a sanitary standpoint than is a woodpecker's hole at a corresponding period. This nest of the hoopoe was on the ground in the midst of a pile of sun-dried brick, and was composed wholly of weeds and lentil-pods. The five young ones, which were at this time nearly ready for flight, showed their fear by erecting their beautiful crests and crawling down among the bricks to hide. There is the further curious anomaly regarding this practise, that some of our most attractive birds, which have delicate and artistic nests, of which I can mention the American goldfinch, do not appear to possess the cleaning instinct at all, or the attendant instinct of inspection, and shortly after the young emerge their surroundings become encrusted with filth. This singular fact is, I believe, correlated with the method of feeding described above. The young are fed at rather long intervals; at one period, of nearly seven hours, the average was once every twenty-five and one half minutes, and all are rapidly,

and repeatedly fed at the same visit. Indeed the movements are so rapid that it is not certain that they are effective in every case. These conditions lead to irregular muting, and to practical difficulties in regard to the sanitation of the nest, or more particularly of the nest-site.

To the acts recorded above we have to add (*g*) incidental behavior at the nest, more or less related to care of the young, as brooding, shielding or spreading over the nestlings in heat (Figs. 1 and 2), or rain, whether sitting or erect, bristling, puffing or swelling out the throat,—possibly with air-sacs distended,—preening, gaping in hot weather, stretching and yawning, with the guarding and fighting in-

FIG. 7. BLACK-BILLED CUCKOO APPROACHING NEST WITH FOOD. First stage in reaction of nestlings; wings vibrating in young which gives most vigorous response.

stincts, called into evidence as occasion may arise. Sporadic additions are sometimes made to the nest, and I have seen the white-bellied martin return to her nest-box a feather which the wind had blown out (Fig. 13). Eagles and hawks will occasionally bring fresh sprays of hemlock or seaweed to their eyries and the great herring gull while incubating or brooding will sometimes bend over and pull fresh grass and weeds within the reach of her bill, and tuck them under her body. Most of these acts are probably instinctive in origin, but they are far from predictable.

It would be safe to affirm that the cuckoo or the cedarbird which we happened to be watching, would in the course of time come to a certain branch, look about, advance to the nest along a certain path, marked out previously by habit, test the throat of one of the eager young, watch for the swallowing reaction, inspect and take the sac, if forthcoming, in the bill, but here no one could say whether the sac would be borne away, and the bird return thereafter with food, or whether it would be eaten, and the bird remain at the nest to brood. Here association and other elements seem to enter. My records for the cuckoo show that the brooding intervals, as to their length and fre-

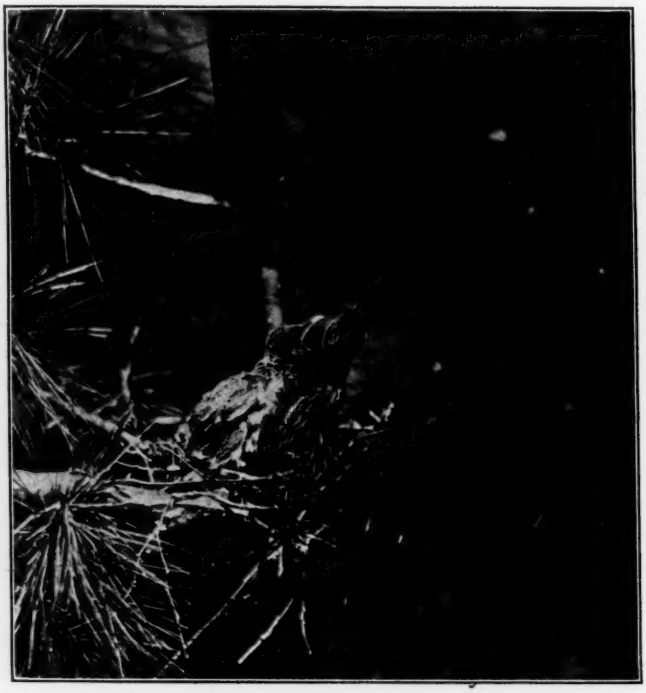

FIG. 8. CUCKOO PLACING FOOD IN THROAT ("testing" the throat); wings of nestling at rest. One bird only receives food.

quency, seem to depend upon the intensity of the light and the activity of the male. During the early period of nest-life many birds brood through the night, but at intervals only during the day. When the sun becomes suddenly obscured with dense clouds, or it grows dark with the approach of rain, brooding is likely to begin, and if the male ceases to bring food, the brooding intervals are prolonged. Thus, during a heavy rain storm I have known the black-billed cuckoo to brood for the space of one hour and forty minutes, and only retire at last at the approach of her mate with food. After his task was ac-

complished, the female returned with an insect, and resumed her brooding again.

The instincts of the parent and young are of the lock and key order. Each acts as a stimulus to the other, and the reward of satisfaction to the child is no greater than that of pleasure to the parent. The co-ordinated instinctive responses of the young begin in many of the precocious birds, like the great herring gull, before birth. The egg is starred and pipped, and the bill of the little bird is seen, and its call note heard, for several hours before the shell is cracked open. The

FIG. 9. GOLDFINCH FEEDING SEED-PAP BY REGURGITATION. Note uniformity of response.

split may occur with a certain degree of uniformity in the direction of the minor axis of the egg, thus dividing it into two equal or unequal parts, and when the chick crawls out it leaves, besides the shell and its membrane, the allantois, and what looks like a residue of the albumen. The shells which now encumber the nest are carefully removed by some birds, and dropped, presumably at some distance away, while in others they are brushed aside, or crushed by the brooding bird and receive no further attention. This removal of the shells so common in the Passeres and other orders, must be attributed to the cleaning instinct, and I have noticed that in the cuckoo, which removes the shells of the first two or three young to hatch in succession, is apt to leave those of the last when the cleaning instinct is on the wane. The allantois is sometimes picked out of the shell and eaten, as has been seen in the case of the gull.

FIG. 10. GOLDFINCHES PYRAMID OF FIVE YOUNG AND ONE ADULT AT LATER STAGE IN NEST-LIFE. Type of direct feeding by regurgitation, where all birds are served at each visit, and some more than once. Note uniformity in response and in size of the nestlings.

The initial instincts of the young depend upon the degree of development attained at birth, and are manifested in every phase from a precocious bird like the snipe, which is born seeing and with a full coat of down, to the altricious cedar waxwing, which is stark naked, and is blind up to the second or fifth day. The precox emerges with feathers wet with the amniotic fluid, and remains at the nest at least long enough to dry off, while the more slowly maturing hawk or eaglet, though down-clad and alert from the first, is tended for weeks or months at the nest. MacPherson, who has described the home life of the golden eagle, which he carefully watched on a cliff in the highlands of Scotland, found that the young were fed at the eyrie eleven weeks before they were ready for independent flight.

The initial responses of the altrix, of which the cedarbird, and, with some qualification, the cuckoo, may be taken as a type, to be seen at birth or shortly after, are (*a*) the power of orientation, (*b*) the grasping reflex of the feet, (*c*) the food-response, (*d*) the call note, and (*e*) the characteristic actions in muting, following feeding, as a result of the stimulus of food, and possibly of the attitude of inspection assumed by the adult. Later follow other specific call and alarm-notes, pecking, gaping, stretching, spreading in response to heat, preening, bristling and certain attitudes expressive of fear, flapping and flight.

After leaving the nest, we observe the more perfect performance of activities already begun within it, as pecking, crouching, standing erect with head upturned so admirably illustrated in the cuckoo, and especially in the cedar waxwing, where its use for concealment is obvious, as well as following, hiding, play, imitation, preying, and the more perfect expression of flight, finally followed by migration in late summer or fall, which may be performed, as in the cuckoos, quite independent of the parents.

IV

The description of the reproductive cycle given above is a composite, and applies most completely to the altricious birds, which are born blind and would quickly perish but for timely care of their parents. There are many special instincts in the twelve thousand or more species of known birds, but few of which have been adequately studied, and there are many minor variations in every term of the series, the discussion of which would require a volume.

The power of the parental instincts to banish fear in all classes of the higher animals has been recognized and admired from antiquity, and nowhere is this more clearly seen than in the brooding bird. The ancient Israelites were forbidden to take the mother bird with her young, because at certain times, as one commentator has observed, she will not avail herself of her power of concealment and flight, the ob-

FIG. 11. GREAT HERRING GULLS ON PRESERVE; chicks on feeding spot, watching old bird, and following her movements.

FIG. 12. GULL REGURGITATING, and the young seizing the shrimp, squid, or fish as they leave the mouth or fall to the ground. Type of indirect feeding by regurgitation.

ject of the law being not merely to preserve the game, but to signalize the sanctity of this instinct.

The brooding instinct rises like a fever, reaches a culmination at the time the eggs hatch or shortly after, and then rapidly subsides. At the same time there is a corresponding depression of fear, which returns with the waning of the brooding impulse. Thereafter brooding becomes more intermittent, being determined in some degree by the intensity of light, and weather conditions, with the difference that fear is now in the ascendent, and the element of intelligence, at the plane of association at least, is not lacking. At its first manifestation it affords a beautiful illustration of a pure instinct, adapted to the preservation of the offspring, though attended at times by what blind and costly sacrifice of life can well be imagined.

At the command of the brooding instinct, or at the sight or touch of the eggs, and later of the young, the whole nature of the bird is quickly changed. In his experiments with noddy and sooty terns, Watson[4] found that while neither bird recognized its own egg, the habits of a laying noddy could be almost immediately changed into those of a "sitter" by placing an egg in its nest. Before the appearance of the egg, this bird is shy and easily disturbed, but contact with an egg, and an artificial one at that, seemed to change its disposition

[4] Watson, John B., "The Behavior of Noddy and Sooty Terns," Pub. No. 103, Carnegie Institution of Washington, p. 223, Washington, 1909.

at once, for it would then stay by its nest and strike angrily at an intruder. The reverse of such behavior was further seen when the egg of a "sitter," even after several days of incubation, was summarily removed.

The cedarbird, ordinarily so timid that it will promptly abandon its new made nest if disturbed in the slightest degree, in the course of a few days becomes so "bold" as to submit to any change which the experimenter chooses to make. I have known this bird to stand on its displaced nesting bough, which had been sawn from a tree and mounted on stakes in a field for close-at-hand study, to permit the writer and a companion to approach within three feet and inspect bird and nest at leisure, while the adult assumed that curious bold upright attitude, with beak pointed to the zenith, in which nature seems to transform the actor into a part of the tree itself.

In my work on "The Home Life of Wild Birds" numerous illustrations of the action of this remarkable instinct are given. In one case a flicker, before so wary, for a few days after the young were born, would permit of any liberties, even to the sawing of a large window in the side of her nesting tree, without budging a feather, not even to shake the sawdust from her back, and allowing herself to be enclosed in the hand. In the Bahama Islands I have taken both the yellow-

FIG. 13. WHITE-BELLIED MARTIN returning a feather to her nest, from which it had been blown by the wind the moment her nest-box was opened.

billed tropic bird and the sooty terns from their nests, but was careful in the case of the former to avoid the thrusts of their sharp, stiletto-like bills.

To keep within the more familiar species, and nearer at home, on July 18, while fishing a trout-stream, I passed two robin nests in apple trees, each with three eggs, more or less incubated. Note the difference in behavior on the part of their occupants, doubtless due in part to difference in individuality. In passing within a few yards of nest No. 1, the sitter immediately flew out in a great state of excitement, and shot off her characteristic emphatic alarms. At nest No. 2 I could

FIG. 14. NEST-CLEANING IN THE HOUSE-WREN, which has the practise of removing the sacs and implanting them on the bark of trees.

see the tail of the sitter projecting over the edge of the nest, as I walked under her tree. This was poked with the fishing rod, but with no response. Then I separated her tail-feathers with the tip of the rod, and poked harder. At this the old robin faced about and pecked angrily at the rod, and snapped her bill with the address of a flycatcher. Then I ruffled her already erect crest and back-feathers, only to receive more thrusts and snapping from the bill, and it was only after the roughest kind of treatment that this bird was finally dislodged, so that I could examine her nest.

To give a final illustration of the working of this instinct, on July

19, at eleven o'clock, I discovered a black-billed cuckoo in the act of brooding one young bird, a day old, and three eggs, in a small sapling pine, about three feet from the ground. The sitter, thus surprised, quietly retired and sounded her alarm from a distance. Twenty-four hours later, when I visited the scene, and when, as afterwards appeared, a second young bird had emerged, fear was more in abeyance, and the behavior different. I was allowed to approach as close as possible, and stood for twenty minutes, with the eye of the sitter not over twenty inches from my own, and only finally sent her off by trying to take her in the hand. Under these circumstances the cuckoo behaves much like the cedarbird, raising its head, though in a less marked degree, and remaining perfectly quiet, the only motions visible being those of breathing and the momentary flick of the third eyelid or nictitating membrane across the pupil.

V

The dawn of avian intelligence in the nestling, if one of the altrices, begins at about the third day, and in relation to the feeding reaction. Resting upon its huge pot-belly, as a central pillar, the little bird raises its trembling head, rather feebly at first, and supporting itself also, it may be, with its wings, and opening its mouth to the widest extent, thus displays its food-target. If the sign is unanswered, the head drops, the mouth closes, vibration ceases, and the bird lies prone, as if exhausted, the whole operation, which seems to call into play the entire body, lasting three seconds, more or less, according to the strength of the original stimulus.

This kind of behavior is a typical illustration of compound reflex action or instinct, and, when feeding follows, the reflexes assume more completely the chain form. When not due to hunger this response may be evoked at will by any suitable stimulus, whether tactile or auditory, whether the bird is in its nest or out of it, and regardless of the parent. The nestling now reminds one of an electrical toy, the action of which is purely automatic. Place the little bird on a piece of cloth or fold of your clothing and "press the button," that is scratch the cloth with the finger or a lead pencil, and behold this complex feeding response. When the nestling has not been fed to repletion, within the limits of fatigue, this reaction may be as automatic, uniform or stereotyped, and therefore predictable, as that of an electric bell.

Initial responses of this sort are relatively perfect. Consequently they can have nothing to do with past experience. They represent the hereditary powers of a hereditary mechanism. Now the point of greatest interest is that this inherited tendency to respond, in the course of a few days becomes replaced, as it were, by an acquired tendency. Instinct becomes "modified" by association. The mind or intelligence

begins to take the reins, though feebly at first, into its own hands. Out of many experiments made upon the young of our common wild birds I select by way of illustration the brown thrush and black-billed cuckoo. In July 24, a nest of this thrush which I had been watching contained three birds, the youngest of which barely had its eyes open, and was from twenty to thirty hours old. When taken from its nest, at 3:15 P.M., and tested in the way suggested above, I obtained one hundred food reactions in thirteen minutes, each representing the entire complex of movements already analyzed, and each lasting from three to fifteen seconds, according to the strength of the stimulus received. A test immediately following gave fifteen reactions to the minute. The reaction time, which was very rapid at first, seemed to slow down only as a result of fatigue, but there was not a single failure to react upon the given stimulus. The same reaction was produced by clapping the hands, touching the bird, or holding its head between the fingers. On this day the two older birds, which were from two to three days old, would react while in the nest, but not when out of it. Now, upon the next day, about twenty-four hours later, as well as upon subsequent days, when the same tests were made with the same birds none of them would react when removed from the nest, with the exception that one feeble response was obtained from thrush No. 3, on July 25.

The same result was obtained with cuckoos. I was unable to get a single food-response from a black-bill, four or five days old, during the twelve hours or more that it was held a captive away from its nest. It would have starved rather than open its mouth of its own accord, and it even regurgitated the food which was pressed into its throat and gullet. Its whole conduct showed conclusively that the sense of fear had not yet appeared, but the moment this hungry bird was returned to its nest, and its feet touched the familiar twigs, it seemed to expand, as by magic, into a new creature, for standing erect, with every feather tube raised, and with vibrating wings, the neck trembling like a tuning fork, it opened its mouth and gave the food-reaction with all the vigor of which it was capable, and gave it repeatedly, loudly calling.

Edinger speaks of the modification of behavior described above, as an acquired habit, by which nestlings assure themselves against impending danger, and compares their attitude with that of an old bird coming hesitatingly to the nest, and looking about as if in anticipation of trouble. A simple experiment, however, like that just given upon the cuckoo, shows that this modification has nothing to do with assurance, for it begins long before there is any decided evidence of fear, and the little bird does not begin to look about in a suspicious manner until it is six or seven days old, when fear is arising. Moreover, all the attitudes, expressive of this instinct, both in young and adult, must, I believe, be considered as instinctive and not acquired.

What association seems to do for the young bird in the first instance is to eliminate a lot of useless reactions, by limiting its responses to those which count, for the amount of energy which goes to waste in this direction, especially up to the time of the later manifestations of fear, near the close of nest-life, must be very great. The pleasure of getting the food seems to lead to an association with the nest itself, the place where the food is received, and with the parent, the active agent, together with her calls and the vibrations of the nest or branches which attend her visits. Association with the nest seems to be strongest, for nestlings up to a late period respond freely to the call-notes of other birds, which happen to pass near, to sudden gusts of wind, at an early period especially, and to violent sounds of every description, like the distant whistle of a locomotive. A more curious sight, which illustrates the indefinite character of this association, is often witnessed up to the very last days of nest-life in many, if not all, of the common altricious birds of the country. Not only does the casual excitement of one bird arouse all the others into action, when, as it were, "the pot begins to boil," and then subsides, but the nestlings often respond to one of their mates, precisely as to the parent, for which it is plainly mistaken, crowding eagerly around it begging to be fed, and in their vain attempts to nestle under it, almost pitching it out of the nest.

In early nest-life, any sudden jarring of the nest or the branches about it will elicit the food-response as readily as when the vibration is imparted by the touch of the parental foot, but discrimination comes in this direction also, at any rate in certain species or individuals, and is often well-nigh perfect at the advent of the instinct of fear.

VI

The acquired habits or tendencies which have been described may in time become very uniform and more or less "stereotyped," but they are widely different from those instinctive characters which alone are inherited.

We have been obliged to speak frequently of fear, which in its origin must be regarded as an instinct in birds. It should not be forgotten, however, that if very young animals of any kind are separated from their parents, so that their natural environments and experiences are changed, we may look for a modification of this instinct, both as to the degree and manner of its expression, and as to the time of its appearance. In all the common altricious birds fear, in its later stages, is attuned with the instinct of flight, or, as in the case of the cuckoo, with the power of helping itself by entry upon a climbing stage, when seven days old. In a cedar waxwing, on the contrary, it is not well matured until the thirteenth or fourteenth day, when the entire brood, standing on their nests with heads upturned, suggest a gun, loaded,

capped and primed, ready to go off as soon as some one pulls the trigger, which is of the hair variety. When this instinct is ripe, the plucking of a single leaf, or any unusual sight or sound will send all off in a panic. They scatter in every direction, making flights both long and good for a first effort, or, if less mature, down they all go flapping to the ground and, if robbins, squealing their danger-signals in high-pitched voices, indicative of that fear which shows in every attitude and note. Correlation, however, is not always perfect, and in consequence of the prematurity of fear many young birds flutter out of their nests in a helpless condition, to meet certain destruction from their numberless enemies on the ground.

That fear in birds may be connate, or present at the time of birth, seems to be clearly implied by an interesting experience reported by Hudson.[5] He was fortunate in finding a nest of the La Plata jacana (*Parra jacana*) on a small mound of earth in a shallow lagoon, with four eggs the shells of which were already chipped. Dismounting from his horse, he picked up one of the eggs and held it for a moment in the palm of his hand, when, as he says:

> All at once the cracked shell parted, and at the same moment the young bird leaped from my hand and fell into the water. I am quite sure that the young bird's sudden escape from the shell and my hand was the result of a violent effort on its part to free itself; and it was doubtless inspired to make the effort by the loud screaming of the parent birds, which it heard while in the shell. Stooping to pick it up to save it from perishing, I soon saw that my assistance was not required, for immediately upon dropping into the water, it put out its neck, and with the body nearly submerged, like a wounded duck trying to escape observation, it swam rapidly to the second small mound I have mentioned, and escaping from the water, concealed itself in the grass, lying close and perfectly motionless like a young plover.

In this remarkable case the whole complex of behavior is as plainly expressive of fear at every step, as it is evidently the free gift of heredity.

[5] Hudson, W. H., "The Naturalist in La Plata," pp. 111–112, London, 1892.

TWO PREVENTABLE CAUSES OF INSANITY

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A FEW successful skirmishes in the interminable conflict with disease happened to take place recently on American soil. We saw the weapons of defense which scientific research had forged for us valiantly wielded by some of our countrymen and a new interest in preventive medicine, which has spread far beyond the ranks of the medical profession, was the result. Such discoveries as the detection of the part played by the mosquito in the transmission of yellow fever and by the rat flea in the spread of bubonic plague were interesting enough to gain a place in the news of the day but it was the fact that the first demonstrations of their surpassing practical value were given by medical officers of the American Army and Marine Hospital Service in our own land that gave rise to the present widespread confidence in the achievements possible in the domain of public health. It is natural, perhaps, that this newly awakened interest in the prevention of disease should center in the infectious diseases, in which the relation between cause and effect is often so obvious and the means of prevention are so logical. The school children of New Orleans easily grasped the simple facts in the case against the yellow-fever mosquito and they became efficient recruits in the memorable campaign of 1905. Much of the success in the present general movement against tuberculosis, the most formidable of all our unseen foes, is due to the fact that nearly all we know of its transmission can be reduced to half a dozen maxims, each of which can be expressed in as many words. It would be unfortunate, however, if popular interest in the battles for the public health should not extend to those diseases in which the relation between cause and effect is one step farther removed.

It is essential that the front presented to the common enemy should be as wide as our present knowledge justifies. There need be no fear of disaster from advancing in extended order, for an attack upon one position of the adversary will not infrequently disclose an unsuspected weakness in another. Since May, 1907, every effort has been made by the combined federal and city forces to rid San Francisco of bubonic plague. With victory assured, the results of what has been done are being counted up and it is found that measures undertaken for the extermination of plague have brought about a sanitary

regeneration of the city and that the mortality from all diseases has been reduced to an unprecedented figure. We know that efforts for the public welfare often produce results where they were least expected, and so, the different fields of preventive medicine, special as some of them seem to be, are really inseparably related. Contrary to general belief, the prevention of insanity is not a matter which depends upon such special factors that it does not concern us all. It is, instead, only a phase of the general warfare against preventable disease; it has points of contact with many familiar problems of sanitation and, as will be shown, it bears a fundamental relation to two social questions which are occupying a very large place in the public attention at the present time.

The prevention of insanity is a matter well worthy of some consideration, for it is doubtful if any other human infliction can produce keener distress. A better conception of the nature of disorders of the mind and a kindlier attitude toward the insane have done a great deal to improve the lot of the sufferers themselves, but nothing can do much to lessen the unhappiness which insanity brings to others. It is difficult to tell exactly how prevalent insanity is. A few years ago some writers, who failed to take account of factors which greatly modified their statistics, startled the public in England by showing that the total number of the insane was increasing at a much more rapid rate than the general population, and one of the more gloomy of these writers did not hesitate to predict that insanity would ultimately engulf the race. It was, of course, absurd to ignore the effect, in increasing the aggregate number of insane persons under treatment, of an increasing readiness to seek institution treatment on account of the enormous advances in standards of care, of the earlier recognition of mental diseases and of the effect of building more hospitals, thus affording ready access for cases not often committed to distant institutions. At the close of 1908, there were 30,456 patients in the public and private institutions for the insane in New York state; about one in 280 of the general population of the state. This is approximately the ratio which exists in neighboring states and, it happens, exactly the same as the ratio in England. This number is not, fortunately, a satisfactory index of the prevalence of mental diseases, for the reason given and because the duration of some mental diseases is so great, in patients who do not recover, that the aggregate number under treatment at any given time represents, in large measure, the accumulation of unrecoverable cases admitted in former years. A patient died recently at the Utica State Hospital who had been admitted in 1843; she had been counted in 65 annual enumerations. The number of patients *admitted for the first time to any hospital for the insane* during a specified period is a much more trustworthy guide. Last year 5,301 patients

were admitted for the first time to any hospital for the insane in New York state; one in 1,600 of the whole population or one in 1,000 if only those above the age of sixteen are considered. Here, then, is our problem in the prevention of insanity. Was it possible, by means at our command to have saved any of these unfortunates from becoming insane last year? Must an equal number, the population of a large town, be admitted next year, another 5,000 in 1912 and so on in the years to come? Are there facts at hand which point to practical measures of prevention or are the causes of mental disease so little understood or so deeply rooted that this sad toll of 5,000 new cases in a single state must be paid each year without hope of reducing it in the future?

Those who are responsible for the care of the insane in the various states are deeply impressed with the necessity of being able to give definite answers to these questions. In preventive medicine accurate knowledge must precede action and so statistics are being carefully gathered and analyzed in order that reliable information may not be wanting in this field of the prevention of disease. The New York State Lunacy Commission, which is charged with the care of nearly one fifth of all the insane in the United States, has recently adopted a greatly improved method of obtaining statistical data regarding new patients and already sufficient material is available to permit the accurate statement of some conditions which could be presented previously only in a general and rather unconvincing way. So, in this discussion of two preventable causes of insanity, it is worth while to examine the records of the 5,301 "first admissions" in New York state for the year which ended September 30, 1908.

At the very outset of any consideration of insanity, it is necessary to make it plain that we have to do not with one disease, manifesting itself in different ways, but with a number of diseases, differing very greatly from each other in many important respects. What is true of the causes or of the clinical characteristics of one mental disease may be entirely untrue of another. Various mental diseases, or "insanities" as it would be quite permissible to call them, are grouped together because of some similarity, and all these groups make up insanity as that term is generally used.

The mental diseases of one such group have the common characteristic of depending upon a preceding infectious disease. Permanent or transitory mental impairment may follow typhoid fever, influenza and some other acute, infectious diseases and it is obvious that these mental disorders are preventable in just the measure in which the diseases upon which they depend are preventable. The number of these cases is not large, and yet, when the cost of the needless prevalence of typhoid fever is estimated, these more remote effects should be considered.

There is, however, one mental disease depending upon a preceding infectious disease which overshadows all others in importance. This is general paralysis or "general paresis," "paresis" or "paralytic dementia" as it is variously known. Almost invariably fatal within a few years after its onset, often a danger to the reputation or to the happiness of whole families in its earlier stages and distressing in its final phases, this disease occupies a place of its own in the interest of physicians and of others who chance to become familiar with it. Six hundred and sixty-four patients, or 12 per cent. of all the 5,301 new cases admitted to the New York state hospitals last year, had general paralysis. Some comparisons with the prevalence of other more familiar diseases may make the significance of this number clearer. Last year there were 1,368 deaths from typhoid fever in New York. Half as many persons died of general paralysis. Cancer of the breast is a relatively common and a much-dreaded disease, yet there were more deaths from general paralysis than from cancer of the breast. Angina pectoris is another frequent cause of death, but more people die of general paralysis. More people died in 1908 in New York from general paralysis than died from smallpox in the whole registration area of the United States in that year and the three preceding it.

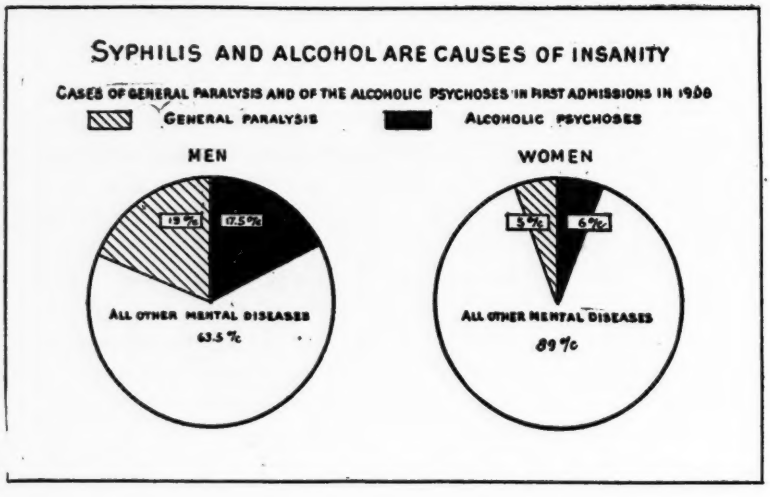
The fact about general paralysis which is of the greatest importance is that it depends upon previous infection with syphilis. To just what extent it is not possible to say, but, whatever other causes may combine to produce general paralysis, testimony is increasing that syphilis is essential. In other words, if these 664 men and women had not had syphilis, very few of them would have had general paralysis.

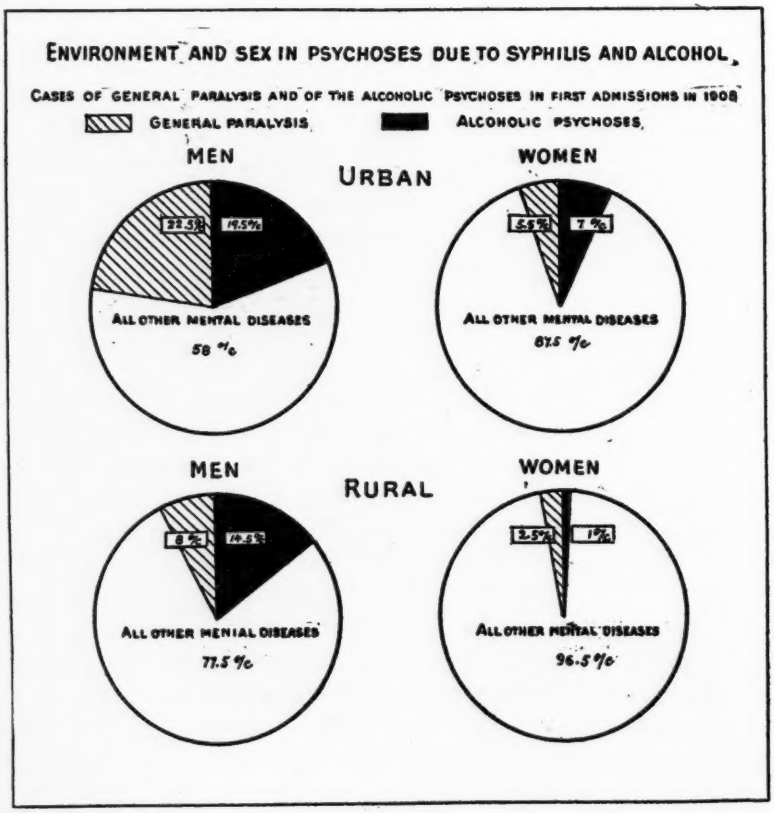
Whatever is to be accomplished in the prevention of disease by the medical profession and an enlightened public will be brought about by concerted action. Without authoritative information and skilled leadership, popular movements in this field will be unlikely to succeed and may even result in harm, and, without popular support, the efforts of doctors will end in academic discussion and in plans incapable of execution. In this alliance frankness is essential; there must be no secrets or half-hidden truths between allies in the battles which are to be fought together for the public health. So the prevalent belief that syphilis is a menace only in an underworld of criminals, prostitutes and the utterly depraved must be abandoned, and the truth realized that it is a peril from which no class of society is exempt and to which the thoughtless, the innocent and the immoral are equally exposed. Three fourths of the 664 cases of general paralysis were married and 69 per cent. of them were in comfortable or affluent circumstances. The most unfortunate feature of general paralysis is that it occurs most often in the third and fourth decades of life; frequently in those who have long since abandoned the immoral or heedless mode of life

which led to their infection and have become responsible for the support of families and of economic value to their communities. It not infrequently means that an innocent mother must be taken from her home, and even from the cradle of her baby, to pay, in mental darkness, a dreadful penalty for her faith in the man who became her husband.

Turning again to the cases we have selected to examine for preventable causes, we find that there were a very large number of patients in whom alcoholic intemperance was the cause of their mental disease. There is no subject which needs to be discussed with so much conservatism or with such scrupulous regard for accuracy as the effects of alcohol. So much in the relation of alcohol to social and bodily ills is the subject of bitter controversy, and so much damage may be done a worthy cause by careless or ambiguous statements that it seems desirable to define very precisely what we mean when we speak of alcohol as a cause of mental disease. Alcohol has been assigned as the cause, directly or indirectly, of more than one half the admissions to hospitals for the insane by Kraepelin of Munich, a very great leader in psychiatry and perhaps the foremost worker in Europe in the cause of temperance. In order to remain upon unassailable ground in this important matter, we will consider separately those cases in which alcohol is *directly* responsible and those in which it was a controlling and probably the only cause. So the facts relating to the "alcoholic insanities," those in which to name the disease is to give the cause, will be presented first. In our series of 5,301 first admissions there were 638 such cases, or about 12 per cent. of all.

There were together, then, 664 cases of general paralysis (depending upon syphilis) and 638 cases of the alcoholic psychoses (all due to intemperance) or *more than one fourth of all first admissions due to these two preventable causes.* Before considering any measures of prevention, it is desirable to examine a little in detail these 1,302 cases because there are some matters of sex and environment which are particularly significant. It is seen in the smaller chart that, as would have been supposed, both these causes affected men to a much greater extent than women. A factor which bears directly upon preventive measures is shown in the larger chart, which indicates the residence, as "rural" and "urban," of patients admitted with general paralysis and of those with alcoholic psychoses. It is seen that in the case of male admissions environment did not have a very marked influence upon the prevalence of the alcoholic psychoses, but that the percentage of cases of general paralysis in men was nearly three times as great in the admissions from cities as in those from the country. For women, this chart shows that the percentage of cases of general paralysis from cities was twice that from rural communities, but that the percentage of admissions with alcoholic psychoses was seven times as great for


SYPHILIS AND ALCOHOL ARE CAUSES OF INSANITY
CASES OF GENERAL PARALYSIS AND OF THE ALCOHOLIC PSYCHOSES IN FIRST ADMISSIONS IN 1908
GENERAL PARALYSIS
ALCOHOLIC PSYCHOSES
MEN
19%
17.5%
ALL OTHER MENTAL DISEASES
63.5%
WOMEN
5%
6%
ALL OTHER MENTAL DISEASES
89%


ENVIRONMENT AND SEX IN PSYCHOSES DUE TO SYPHILIS AND ALCOHOL
CASES OF GENERAL PARALYSIS AND OF THE ALCOHOLIC PSYCHOSES IN FIRST ADMISSIONS IN 1908
GENERAL PARALYSIS
ALCOHOLIC PSYCHOSES
MEN
URBAN
WOMEN
22.5%
19.5%
ALL OTHER MENTAL DISEASES
58%
5.5%
7%
ALL OTHER MENTAL DISEASES
87.5%
MEN
RURAL
WOMEN
8%
10.5%
ALL OTHER MENTAL DISEASES
77.5%
2.5%
1%
ALL OTHER MENTAL DISEASES
96.5%

cities as from rural communities. This is eloquent testimony to the influence exerted by the back room and the "ladies' entrance" of the city saloon. The most striking fact shown by these charts, however, is that *42 per cent. of all the male admissions from cities were for general paralysis and the alcoholic psychoses.* Where are "the nervous tension of the cities" and "the mad rush of modern life," of which we speak so glibly, compared with syphilis and drunkenness as the real dangers of city life? But for the undue prevalence of insanity due to these two causes, the ratio of the insane to the population would actually be greater in the quiet countryside than in the cities, in spite of their congestion of population, their unequal share of immigrants (an important factor in the prevalence of insanity) and their increased economic stress.

All through the etiology of other types of mental diseases than those which we have considered, appears the trail of syphilis and intemperance; sometimes unmistakable and sometimes faint but recognizable. A considerable percentage of the 5,301 first admissions were for mental diseases arising upon a basis of congenital mental defect or epilepsy. Some of these psychoses are temporary attacks in epileptics and in imbeciles and some are really terminal stages of such conditions. The tremendous effect of alcohol in the parents as a cause of mental deficiency has been pointed out by many competent observers and there are many very interesting studies which could be mentioned if space permitted. Alcoholism in parents has nearly as great an influence in the causation of epilepsy as of mental defect in descendants. Dr. R. E. Doran found that the parents of 257 of 1,300 epileptic children admitted to the Craig Colony had been confirmed alcoholics. A group forming about one tenth of all admissions to state hospitals is made up of patients with psychoses dependent upon gross disease of the brain. In these mental diseases there is destruction of cells of the brain, resulting from arterial changes, the effects of hemorrhages, the pressure of new growths and similar causes. In a very large proportion of such cases it was syphilis or alcohol which first attacked the integrity of the blood vessels or in other ways laid the train which was destined to lead finally to insanity.

So, if we care to go beyond the field of what is demonstrable by absolutely trustworthy statistics and can be shown by tables and charts, we find that alcohol and syphilis are factors in the production of mental diseases which have no equal. If we prefer to confine our attention to general paralysis and the alcoholic psychoses, we find that these diseases, due *directly* to syphilis and alcohol, are responsible for nearly one fourth of the sad procession of new patients entering the hospitals of a single state at the rate of more than a hundred a week.

The lesson of these statistics is full of hope and encouragement.

A large proportion of all cases of insanity are found to be due to causes within our own control. We have come across the trail again of two formidable enemies, but they are old foes and we know their strongholds; we have been gathering evidences of their depredations in other directions and there are already movements on foot against them. We have gained the tremendous advantage of being able to talk about both of them in public and before any hearers. Instead of vague tales of the ravages of these enemies of the race, in one direction or another, we have come to statistics, tabulations, investigations with reference to specific effects and to the widest publicity. This is why it is justifiable to speak of syphilis and alcohol as two *preventable* causes of insanity.

THE INDIAN FAIRY BOOK

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AFTER our boyish occupation of following cows home from pasture, along brambly ways where delay was often invited by some untimely mocker in the shape of a bird that lured us into pursuit, we would go up in the gathering dusk to the house on the hill and listen through the hour before supper to the stories in the Indian Fairy Book. Stillness and an autumnal glimmer of western light; crisp air laden with the smoke of smouldering brush fires—these ever after to be blent, by the subtle alchemy of memory, with the tales of an ancient people. Beyond the sunset light lay the land where these stories had been wrought, yet a country that none might reach by traveling in mortal fashion, for, like the old Phæacian land, it belonged in those dim regions of the past that only the eye of fancy may behold. We had mapped it out in our minds—its lakes and wide prairies, its farthest verge of forest—but no explorer we knew would ever find it. He might stand on the marge of some far western lake, never before seen by a white man, and gaze across its waters, yet this elusive land would ever be another day's journey beyond his last camp fire.

In this Indian Fairy Book were gathered the folk tales of aboriginal America—Algonquin and Dakota legends, that might fairly hold a place with those old Celtic tales—the Mabinogion—that have come to us out of so remote a past. Indeed, they have many points in common. Magic weaves its web through the adventures of the men and women who seem more than mortal beings and who yet give to the wonder tales in each of the two groups their vital human interest. In each also there are great personages, cast in heroic mould. There is the same overcoming of evil influences, the same mystical union of men with natural things. Both are of that Juventus Mundi—that far away period over which a strange, dim light broods. It is this effect of subdued light, the strange half light, half dark of a shadowy world, that a reader of these aboriginal tales feels most. A "twilight" effect, Mr. Havelock Ellis calls it in writing of the Celtic tale, which lends a peculiar "glamour." And, as this writer has further shown, the effect of "remoteness" as to time and place, of being very far removed from the present or even the medieval world, is another element that adds to this glamour of the old Celtic stories. Sidney Lanier says:

> I think it curious indeed to note *how* curious those old romances, or Mabinogion, seem to us in spite of the long intimacy and nearness between Welsh and English. They impress most readers with a greater sense of foreign-

ness, of a wholly different cultus, than even Chinese or other antipodal tales; and over and above this there is a glamour and sleep-walking mystery which often incline a man to rub his eyes in the midst of a Mabinogi, and to think of previous states of existence.

It is this sense of strangeness, this "sleep-walking mystery," as Lanier calls it, that haunts the aboriginal American tale. It is of the same cultus as the Celtic, and both loom above the horizon of later English culture as distinctly aboriginal and belonging to preexistent races that occupied the soil ages before the transplanting of the dominant English type in Britain and America. Like the vanishing fauna of an invaded land, these ancient culture tales linger in remote places, amid aboriginal surroundings, elusive, and disappearing with the encroachment of the newer life.

In the early years of the last century Henry Schoolcraft gathered a number of Algonquin folk tales taken directly from aboriginal story-tellers around lodge fires in the then remote wilderness of the Northwest—about the upper lake region and the headwaters of the Mississippi. These form the basis of his "Algic Researches," first published in 1839, and of later editions and compilations, one of which is the Indian Fairy Book. What Geoffrey of Monmouth did for the Celtic romances in his "History of The Britons," Schoolcraft has done for these Algonquin legends—given them an enduring place in the literature of English-speaking peoples. Both sources of legend have lent their matter to the verse of later English poets—Idylls of the King, the Morte d'Arthur and Hiawatha—reset fragments from an earlier period of epic the sources of which lie far back in the dim, mythopœic past.

The likeness of the primitive mind in two so widely separated culture areas as Britain and aboriginal North America, as revealed in both sets of tales, is seen in the overcoming of obstacles, often of superhuman character, by feats of prowess aided by magic. Indeed, magic plays the chief part, as it does in the tales of all primitive folk. In an Ojibwa story—The Red Swan—a younger brother sets forth in quest of a mysterious bird that he has hit with a magic arrow. He traverses wide stretches of country, coming on the evening of the second day to the lodge of an old magician who feeds him from a magic kettle and who encourages him to go forward in his enterprise. "Often has this Red Swan passed," the old man tells him, "and those who have followed it have never returned: but you must be firm in your resolution, and be prepared for all events." On the evening of the third day he reaches the lodge of another old man, similar in every respect to the first, and in like manner a third old man entertains him the following night, each with the same magic kettle. When the youth has finished eating this last old man thus addresses him:

Young man, the errand you are on is very difficult. Numbers of young men have passed with the same purpose, but never returned. Be careful, and if your guardian spirits are powerful, you may succeed. This Red Swan you

are following is the daughter of a magician, who has plenty of everything, but be values his daughter but little less than wampum. He wore a cap of wampum, which was attached to his scalp; but powerful Indians, warriors of a distant chief, came and told him that their chief's daughter was on the brink of the grave, and she herself requested his scalp of wampum to effect a cure. . . . The warrior's coming for it was only a cheat, and they now are constantly making sport of it, dancing it about from village to village; and on every insult it receives, the old man groans from pain. . . . The Red Swan has enticed many a young man, as she has done you, in order to get them to procure it, and whoever is the fortunate one that succeeds will receive the Red Swan as his reward.

This is the key-note of the tale. The youth by magic assumes various forms—a humming-bird, a bit of floating down, a hawk—secures the scalp and restores it to the old magician who immediately becomes a young man and ultimately bestows upon his benefactor a maiden of wondrous beauty, the erstwhile Red Swan.

This tale has in it many points of resemblance to a Mabinogi. In the old Welsh story of Kilhwch and Olwen, for example, there is the same overcoming of difficulties by means of magic, the same transformation of men into animals and objects of nature, the same gaining of some object of vital importance, and the ultimate bestowal of the prize—a maiden of radiant beauty—upon the successful one. There is much circumlocution and repetition in all of these primitive tales. The difference seems mainly in the setting—the environmental influence, one may call it—not in the substance of the tales themselves.

In the Dakota legend of Strong Desires and the Red Sorcerer we have the story of a youth (it is always youth that figures so heroically in these tales, both Celtic and American) taunted for his timidity, who becomes master of himself by accomplishing the death of an evil spirit in human guise, and who gains his end through the same magical influences that are woven so closely with all the events that take place in this strange world of the past. So in other of these aboriginal American folk tales—The Vanishing Little Men (the origin of the fairy people), The White Feather, The Magic Bundle, The Enchanted Moccasins, The White Stone Canoe, The Summer Maker, to quote but a few in passing, one is impressed with their close similarity to the Celtic cultus. In many of the Welsh tales and in such old Irish stories as the Fate of the Children of Lir and The Fate of the Children of Turrenn, there is the same changing of men and women into beasts and birds that one finds so often in the tales of American aborigines. Many of these tales, in fact, belong to that class of curious beast stories that are so widely spread in the culture of all primitive folk. There is hardly a story in which an animal of some kind, with human attributes, does not appear. Men pass into animals or animals take on the speech and ways of men as a matter of course in this land of enchantment. In both the Celtic and American stories, too, there are men of heroic figure. Manabozho, the Hiawatha of the Iroquois, while given, as related

in certain Algonquin tales, to mischief of a more or less harmless character, was a being of lofty nature, and, save for the ruder surroundings of his life, a personage quite as imposing as Arthur himself. Indeed, in the conception of each as a power for good—and this is the real essence of their natures—there is little, if any, difference.

The modern world can not but miss the drift of these stories, for the mind that conceived them belonged to the youth of a race. Men of to-day have so far forgotten this period of racial childhood (as they have forgotten their own individual childhood), have so far put behind them the childish things, that they largely fail to grasp the real meaning of these tales. It was the earliest glimmer of that racial self-consciousness that in after times found expression in self-narrated history and in religious belief. The type or mode of thought was the same in all races when they reached this crisis in their psychic development—a realization of kinship with the powers of earth and air, with the phenomena of nature, and with the life of animals and plants. Child-like efforts to account for the origin of things gave rise to those strange creation myths that exist as primitive conceptions in the history of every race and people. Delusions of judgment undoubtedly played a large part in the myth-making faculty of primitive men. They verily believed that they saw and heard strange forms, unembodied voices. They were overawed in the presence of elemental forces and, child-like, they saw in all the lineaments of nature mysterious powers, potent for good or evil. The sights and sounds of nature and the ways of animals were interpreted by them in terms of their own mode of thought. To the phenomena of cause and effect, to the haphazard circumstances of their own lives and those of their fellowmen—fortuitous and unfortuitous happenings—and to dreams, they imputed the agency of superhuman powers or magic. To this latter class of phenomena—dreams—we may attribute much of that curious recital of visits to the underworld. In the Red Swan, for example, the hero of the tale, after his return to his native village, journeys to the abodes of the dead, where he holds converse with the chief of the departed buffaloes. One can not help but be impressed, in reading this portion of the tale, with its resemblance to the visit of Odysseus to Hades.

These myths and folk stories have drifted down to us out of so remote a past that the period which they depict in the history of any group of peoples can never be certainly known. More than likely they are the embodiment of a slow subliminal growth that began with men of paleolithic culture in various parts of the earth as a result of the impress of their surroundings. At a later period, possibly in a neolithic stage of culture, as in aboriginal America, this body of impressions crystallized into the form of the myth and the folk tale. Homer depicts the Bronze Age, which was later than that of stone, and the Celtic tales are probably of this period also, but there are no means of knowing where the germ of any myth or story had its origin, for much new

matter has likely been grafted upon an older form and the whole tale has come to represent a slow accretion from one generation to another through many phases of culture and over vast periods of time. Whether a race of dwarf men inhabited lands that were later invaded by men of larger stature and more advanced culture and gave rise to conceptions of gnomes and "little people," as suggested by Sir Harry Johnston, is a matter of purely speculative interest. As this writer has pointed out, the African forest pygmies, who represent a very ancient type of man that was once widely spread in Europe, as well as in Africa, have certain characteristics, as suddenly vanishing from sight and as suddenly appearing, that might well have given rise to folk myths. Such may have been the origin of our Santa Claus, a hyperborean dwarf-myth arising out of the reindeer-herding Lapps in that dim land beyond the Scandinavian mountains.

The gift of the mythopœic faculty belongs to childhood—individual and racial. Education in the modern sense—the education of the school—is its arch enemy. The rank, tall-growing weeds of knowledge soon choke out this joyous bloom of the aboriginal soil. We enter the school and straightway a mist drifts across our past, blotting out the early years, and the days of romance, and myth, and make-believe are speedily forgotten. Yet out of this enchanted mist—for it is enchanted, like the mist that shrouded Geraint when he left Enid to fight against the knight—some of us may still, in rare moments, have glimpses that will make us "less forlorn." As Geraint dispelled the mist by the overthrow of his adversary, so we must, if we desire these visions, break through the mist that envelops them with the magic arm of imaginative memory, for no weapon of knowledge may serve us in its stead.

The backward extension of each individual life through many generations of germ-plasm carries us all back to a common racial childhood. Much of this racial childhood is recapitulated in the first years of individual existence—old race instincts, strange primitive ways, and the love for stories about beasts, and men, and fairy people. These myths and folk tales are thus part of a racial heritage, and happy indeed are those of us who, in our maturity, can still feel with the poet when he exclaimed—

> —Great God! I'd rather be
> A Pagan suckled in a creed outworn;
> So might I, standing on this pleasant lea,
> Have glimpses that would make me less forlorn;
> Have sight of Proteus rising from the sea,
> Or hear old Triton blow his wreathed horn.

As we love Æsop and Uncle Remus, the Odyssey and the Celtic tales, so we love these folk stories of aboriginal America, for they are of the same lineage—the early, unsophisticated outlook upon life and the Powers of Darkness.

SCENERY, SOIL AND THE ATMOSPHERE

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THE atmosphere is commonly considered as a body of gases surrounding the globe, but hardly as a part of our sphere. We must, however, look upon it as being of the very substance of our earth, an integral part of the planet as truly as the waters or the solid crust. The geologist and the geographer, indeed, habitually speak of three envelopes of the globe, the atmosphere, the hydrosphere and the lithosphere. A certain assemblage of gases, all of which may be found in the waters and the rocks, remains in a more attenuated condition as the outer part of the earth. The degree of attenuation increases as we go from the surface of the solid part. Whether the atmosphere actually ceases a few hundred miles, or some hundreds of thousands of miles, from the lithosphere is not important to our present purpose, for its effective work is done within a few miles of altitude.

Looking at the atmosphere as a whole, its calms are exceptional and its movements are the rule. We may find the gentle breeze, the cyclonic wind or the resistless tornado, but always activity. These movements do not tamely confine themselves to horizontal paths, but the gases rise and plunge, pursue broad curves and narrow spirals, and would present, to an eye that could see them from above, a tumult, like the sea in storm. If we add to these mechanical operations the efficient chemical functions of the atmosphere, we shall be ready to agree that it is one of the most powerful agencies that help to mold the form and fashion the quality of the outer parts of our planet.

We well understand that all organic life is dependent on the atmosphere for its existence, and that interchange of materials is constant. The forms of the land are nearly as dependent upon this medium as are those of life. Manhattan Island was once a mountainous tract. The first making of the rocks that composed it was conditioned by an atmosphere. The forces that filed it down to its present forms and heights could not have worked without the gaseous envelope. The channels that invite ships to its water line are an indirect product of atmospheric activity. Indeed, the Palisades Ridge, and the submergence of the coast line are the only features of your inorganic environment that have chiefly been due to underground forces.

The atmosphere is interwoven with all forces operating on or near the surface. Other, or subterranean, energy could produce but a few types of form. We might have great and swelling ridges or domes, or cliffs due to faulting, involving fracture and dislocation, or volcanic cones, streams or sheet outflows. For such initial forms, apart from an

atmosphere, gravity would seem to be the only agent of change, and its action would be narrow, for disintegrating forces must operate to make gravity effective.

With so much of introduction we are ready to look at the atmosphere in a threefold way—and consider, first, its indirect work; second, its direct work; and, third, its history.

As a means of changing the face of the earth, and of modifying its rocks to a considerable depth, no agency compares with land waters. But we are to remember that waters, if they could exist, could not move without a gaseous medium. Supply our planet with its outfit of oceans, lakes, rivers and underground waters, and, in the absence of a thermal blanket they would be frozen and silent. If they could be conceived as keeping the liquid condition, no transportation of water vapor could take place, no rainfall, and no rivers or glaciers could accomplish their tasks.

Modern geography has introduced the doctrine of the cycle. We mean by this the period in which a continent or any part of it would be reduced from its initial forms of uplift, to baselevel; in other words, the time necessary to wear out a land, and put its waste under the bordering sea. In the course of this wearing out, many land forms—mountains, plateaus, hills, plains, slopes, valleys—would come into being and disappear, in appropriate stages of youth, maturity and age. A great series of evolutionary forms of the land would characterize the passage of a cycle.

The varying amount and condition of land waters give us three types of the geographic cycle and three typical groups of resulting shapes of the surface; these are the normal, the glacial and the arid. The normal cycle is conditioned by medium temperatures and ample precipitation in the form of rains. The glacial cycle exhibits low temperatures and abundant precipitation in the frozen condition. The arid cycle is marked by higher temperatures and low precipitation—so little rain that lakes can not rise to the rims of closed basins due to warping of the crust, for the simple reason that evaporation and soakage take care of the rainfall and no rivers can reach the ocean.

We may illustrate the three kinds of cycle by three well-known parts of our own land. The southern Appalachians show us what happens in normal conditions. There are indeed at least two cycles whose results are clearly shown in this southern region, but for our purpose we simply observe that here are plentiful rainfall and moderate temperatures. Great initial uplifts have given opportunity for land sculpture on a large scale. Rivers and weathering have done the work. There are practically no closed basins, either dry or wet, no interruptions of drainage, and the soil is residual, having been chiefly made by the decay of the rocks in place.

Let us turn to New England. Here the soils are due to the weather-

ing and organic modifications of the "drift." The drainage has been greatly interrupted, and new channels, waterfalls and lakes abound. Several types of hills of accumulation appear that we can not find in the southern mountains. The tops of hills and mountains of hard rock have a different aspect—it is the product of the glacial cycle which we are contemplating, and the geographer would only need to cast his eye upon maps of the two regions to recognize their character.

Let us go to the Great Basin. Rather is it a group of basins, flanked by the Wasatch on the east and the Sierras on the west. Its broad and arid expanse is intersected by many north and south mountain ridges, which are the up-thrown edges of great crustal blocks. The upper parts of these mountains show normal erosion. The bordering Sierras show normal and glacial types. Within the basin the summits and slopes of the mountain are shedding down their waste and streams of greater or less vigor are carving a normal topography. At the foot of the mountains, the waste, instead of going in the grasp of streams to the sea, is spread out on the inter-montane floors, raising the surface and building plains of sand, clay, salt and gypsum. The rivers become small instead of growing, and lose themselves in the atmosphere, the soil and in shallow lakes which may be permanent and salt, or intermittent and brackish. The soil is formed mechanically and with but a minor amount of those chemical changes which take place in a more humid climate. Vegetation is scant and this condition retards true soil-making and, by lack of cover, aids the action of winds. Monotony characterizes the arid type, as ceaseless variety belongs to the normal and glacial operations. The ridges that separate adjacent arid basins may be cut away, and both be merged in a single featureless plain, and thus we have a growing lake of waste, somewhat akin to closed basins of water. The only means by which such a basin can lose its material is through the winds. Central Persia offers another land of the same order, where severe conditions of aridity have for an unknown period reflected themselves in the life of man and in the very forms of the land which he makes his home.

Hill and mountain, valley and plain, thus own their dependence, in no remote way, upon the gaseous envelope. As it is wet or dry, hot or cold, so evolves the very physiognomy of our globe, and whether we cross the border of an adjacent township or journey to a far country, its handiwork is before our eyes.

No forms are more characteristic or interesting than those which the ocean makes on its borders. These forms in a minor way are due to the tides, in the major way to waves, and thus, at one remove only, are produced by the atmosphere. Likewise ocean currents, involving transfers of heat, moisture, plants and animals, are believed to be chiefly due to atmospheric movements. If we compare New York with Rome and Constantinople, or Labrador and Hudson Bay with Great

Britain and the North Sea, or the ice fields of Greenland with the ample life of Scandinavia, if we wonder at the small part which latitude seems to have with opposite shores of the Atlantic, we are at once led back to the atmosphere for light upon our problem.

Likewise for all life, the atmospheric gases are essential as a heat regulator and in the employment of their substances for organic structures. Through these structures, in turn, all soil-making is profoundly conditioned, and those organic accumulations are made possible, which we find in the mineral fuels and in most limestones.

If we turn to the direct work of the atmosphere, we shall find a group of facts, not so conspicuous, perhaps, but worldwide and important. This is one of the newer subjects in geology, and to consult any text-book written twenty years ago would yield a scant result in information.

The atmosphere is the agent of incessant chemical change, the world over, and down to the level of the ground water. Whether the water table be found close to the surface or far down, the atmosphere finds access to some parts of the rocks down to that horizon. The depth below the surface depends on the water supply, on the character of the rocks and on the surface topography, and it is different in the same place at different times, but always and everywhere the gases that surround and surmount us, are pursuing their underground activities as well. And it is scarcely proper to limit them to zones above the water table, for they communicate some measure of their efficiency to the ground waters, which in turn may go far down, and may make long journeys before they emerge, thus giving the atmosphere some share in the segregation of those metallic substances which belong in the inventory of the world's wealth.

The making of soil is a complicated process, or bundle of processes. Fundamentally it is due to the breaking down of rocks, and this is effected by change of temperature, by organisms, by the wear of running streams, glaciers and ocean waves. But when the rocks are broken down, processes more intimate and essential must be added. These more intimate agencies are the water, the atmosphere and decaying organisms. The water will accomplish solution and thus make certain minerals available for the nutrition of crops. But the water falling as rain has gathered from the atmosphere minute portions of its carbon dioxide, and has become thereby an effective dissolving agent. Most rocks contain more or less iron in a disseminated condition. The oxygen of the air combines readily with this metal, promoting the decay of the rock mass, and coloring not only the rock, but the soils that ultimately come into being. When the farmer selects a field to lie fallow he stirs the soil, gives it all possible exposure to air, water and heat, and thus speeds these silent processes which go on in some measure everywhere, with or without his ken. It is the time required to produce

these fine results, that makes wanton destruction of soils criminal and points the rebuke to public authorities and legislative bodies, when they halt at reasonable measures of conservation. We can not grind rocks in a mill and make soil. The operation is at once too large and too delicate, demanding the silent intervention of mechanical and chemical forces, of atmosphere, water, heat and life, through long periods of time.

When the land has suffered a glacial invasion, much of its ancient soil has been lost in the sea, and such as remains is moved from its place and mixed with a large body of drift, mechanically broken from fresh bed rock. This latter material is not soil until it has been subjected to the atmospheric and vital processes which fit it for its function of mediation between the rocky planet and the plant life of the world.

In a non-glacial region, all the soils, save along rivers, or on steep slopes, have been formed by the decay of the bed rocks in place, and this decay does indeed, and fortunately, in favored regions, proceed swiftly. It may be some compensation for people subject to disaster on the slopes of Vesuvius or Etna, that the friable lavas and ash, in that genial climate, speedily become soil. On a lava stream still warm, at the foot of Vesuvius, baskets of earth, suitably spaced for vines, have been deposited, and the lava itself in a year or two will be hospitable to the roots.

Stone from the quarry is popularly thought to be a durable building material, but only the most compact and resistant varieties, and these in a favorable climate, can make any approach to permanence. Granites are regarded as indestructible, but the title of granite to serve as the standard and symbol of strength is clouded when we remember that many beds of soft clay owe their accumulation to the decay of one of the chief mineral constituents of this rock, a decay in which the atmosphere has been a powerful agent. Granite that can be excavated with pick and shovel betokens the ceaseless activity of the gases and waters of the earth's surface.

Some of you will recall the promptness of atmospheric attack upon the obelisk of Central Park after it was transplanted from its arid habitat of millenniums. Many of the beautiful structures of the Oxford colleges, boasting not three centuries of antiquity, are under restoration piece by piece, showing an apparent hoary age through the solvent work of the atmosphere upon their unstable calcareous material. No marble monument has stood in the open air for half a century and retained its polish, and it must have been an exceptional piece of monumental stone if it does not now crack and scale and take on the look of age. Every humid climate with large temperature range introduces a ceaseless struggle with the destructive forces of the atmosphere, whose sum of hostility to the structures of man is far greater than that of flood, fire or earthquake.

The energies of the atmosphere mechanically applied, bring before

us a group of results, not perhaps so nearly universal, but even more tangible and conspicuous. Many agents are at work producing mineral materials of such fineness that the winds can carry them. Oriental travelers and explorers know the sand storm as one of the most distressing and sometimes deadly visitations. In the desert mechanical disruption of rocks goes on rapidly and there is little moisture or plant life to hold the fragments down. The winds become factors of transportation in a manner little known by dwellers in moist and verdant lands. Dust storms are not confined to the Sahara, or Persia, or Turkestan. They occur in considerable numbers in our arid regions, where they sweep for hundreds of miles, last for many hours and carry incredible loads. Sand drifts a foot high have gathered in a half hour on railway tracks; thirteen cars of sand were taken from a single depot platform in Colorado; the same careful student who reports these facts estimates from 160 to 126,000 tons of sand carried in a cubic mile of air. This for a single storm may give us hundreds of millions of tons borne for hundreds of miles. Under such conditions the redistribution of surface materials by the atmosphere can no longer be held trivial.

We are now to remember that desert conditions furnish but a minor part of the dust that is available. Wherever in all geologic time there have been explosive volcanic eruptions, dust has been expelled, often in prodigious amounts, covering leagues of sea with floating pumice, littering the decks of vessels hundreds of miles away, destroying crops, darkening the atmosphere across wide seas, and enriching the sunset glows, it is believed, around the globe. Every rain storm purges the air of dust, much of local origin, no doubt, but some from remote and subterranean sources. Here is ceaseless accretion for all land surfaces and for all sea bottoms, and we have an impressive illustration of the interdependence and the cosmopolitan efficiency of every part of the earth's machinery.

Man never uncovers a soil surface with the plow or by the passage of hoof or vehicle, without exposing material to atmospheric migration, and it is some years since an expert road maker, in a highway convention, set forth the havoc wrought on macadam roads by winds.

From the point of view of natural scenery the winds' most conspicuous product is the dune. Many have seen a single example of a belt or field of sand hills, but the student of the earth finds in them no phenomenon of small range. He looks for them on the lee side of every river in a desert region and along all sand shores. He finds them invading the olive orchards of Palestine, the vineyards of France, the meadows of Holland, the forests of the Great Lakes and the fields of Cape Cod. The hand of man is put forth to stay the ravages of these flying cohorts and the organized skill of a government department joins in the task. Search is made for sand-binding grasses, in the same

spirit in which the agricultural explorer hunts for wheat suited to arid fields or palms for the future orchards of Arizona.

The wind-blown sands are not only materials of accumulation, they are agents of erosion. Deserts abound in bare and unprotected rock surfaces, which occupy thousands of square miles in the Bad Lands, in the ridges of the Great Basin, in northern Africa and in western and central Asia. The impact of sharp-edged grains of quartz, maintained in every wind storm age after age, becomes no small means of wear and destruction, producing a natural sand blast whose principle is now used in many and ingenious ways in the arts. We have interest in Thoreau's quaint story of the clergyman of Cape Cod, frequently setting a fresh pane of glass to preserve the transparency of at least one fragment of window surface, but if we look more widely we find a large and significant phenomenon. Small lake basins have been excavated by the wind, and the sand of desert basins, eroding on its long journey, may come to rest at some remote point, as truly "exported" as if sent across the boundaries of a foreign land.

Before passing from these direct accomplishments of the atmosphere, we must include those peculiar deposits of fine and silty material known to the geologist and the physical geographer as loess. Much has been said of their origin, often in the field of debate, sometimes in the realm of controversy. But these great sheets of material, typically found in the Mississippi Valley, and in the central parts of Asia, have impressed many observers as being in whole or in part the work of winds blowing over vast fields of aridity, or sweeping widely the fine-grained outwash from areas of glaciation.

If we add now the transport of organisms, particularly of seeds, insects and birds, and the influence of winds on the migration of higher animals and man himself, through the medium of ocean currents, we shall see how the face of the organic world gathers its lineaments as broadly and depends on the atmosphere as intimately as the contours of a continent. The organic in turn reacts on the purely physical and we recognize at last that, touch the globe where we will in scientific inquiry we pick up some link in an endless chain.

The climates of the world have not always been what they are to-day. If we go as far back as the records will carry us, we find rocks and fossils that betray the climates of their time. These geologic climates are parts of ancient geographies which, in a long series, lead up to the geography of our own age. Throughout this succession, the atmosphere, its constituents, movements and temperatures held the same influence over the rocks of the crust and the forms of the land, which we now see. The atmosphere has had a history, and its qualities and activities have been among the chief factors in the evolution of the earth's surface.

Geology recognizes many periods of prevailing warmth, in which genial conditions were so wide-spread as almost to amount to a disre-

gard of latitude. These temperate and subtropical conditions in high latitudes belong not only to ancient, but to the middle and modern ages of the world, and geologists long ago surrendered the notion that they could be due to supposed stores of the earth's primal heat.

There have been periods of notable dryness, so that deposits of rock-salt were formed through the evaporation of marine waters. From New York westward occur beds of salt, due to a dry climate, in a region where the rainfall is now abundant and where the basins of the Laurentian lakes are filled to their brims.

Not many years ago, the ice invasion of the Pleistocene was regarded as simple in character and unique in time. We now accept, among the commonplaces of glacial geology, that the late ice invasion was composite, marked by great advances and recessions, and by interglacial times of genial climate. And we recognize further, among the accepted facts of the science, the existence of vast glacial sheets in Permo-Carboniferous times, in India, Australia and South Africa, in regions which are now either warm or warm-temperate, and in lands of no great elevation.

Yet more remote, in the Cambrian, in an age of early life forms, an age recognized by the older geology as having almost ubiquitous warmth, the evidences of extensive glaciation have been brought to light. We must remember that humidity, precipitation, great or slight, and variations of temperature, are intimate questions of meteorology, whether we raise them in Cambrian or Miocene or present times. The meteorology of the passing age is related to geologic climates precisely as the physiography of existing lands is related to the rocks and rock structures of the past. The atmosphere has undergone a prolonged evolution in close association with the progress of the solid earth. As a part of the earth's history the study of the atmosphere is somewhat belated, but its importance is now recognized, and it will fill a large place in the geology of the future.

The present atmosphere therefore has not always existed and is but the latest term in an evolutionary series. We find two leading assumptions concerning this history.

There is a widely prevalent geological doctrine that our atmosphere is a residuum from a more dense or a more extensive body of gases. On this view it once contained all, or much, of the carbon dioxide whose carbon is now wrapt up in the coal and the limestones of the earth's crust. Thus Dana refers to the "purification of the air and waters through the making of limestone" as commencing in later Archean time and continuing through the Cambrian.[1] Accepting, as he does, the idea that all the carbon of the coal and of many rocks was originally in the air and the waters, he still finds difficulty, for in early Paleozoic time life shows an atmosphere not too heavily charged

[1] "Manual of Geology," fourth ed., p. 484.

with this gas, notwithstanding the fact that great coal beds and many great limestones had not yet been formed.

Geikie recognizes a continual abstraction of carbon dioxide since land plants began to live, but only allows that the amount in the air in Paleozoic time may have been somewhat greater than now. Davis thus expresses the view which has been long current:

> Some of the more volatile mineral substances in the rock-crust of the earth presumably at an early time made a part of the atmosphere, but all these have long ago left it. Nearly all of the water that must have once been boiled off in the steaming atmosphere of early times has now condensed upon the cooled surface of the earth, forming the deep oceans. Some of the gases themselves, particularly the oxygen of the air, must have been much diminished by combining with the surface rocks of the earth's crust and rusting them.[2]

These views, it will be seen, follow naturally upon the nebular hypothesis, with its mass of heated gases undergoing consolidation.

We find under discussion at the present time the view that the atmosphere is not greatly different from that of early geological periods, but has been subject to important fluctuations in the amounts and proportions of its constituents. These changes are believed to be due to many causes, some effecting loss and some bringing about renewal. Various interchanges are postulated, on the one hand, between the earth and outside spaces, and on the other between the atmosphere and the crust or the interior of the globe. This line of investigation has been recently pursued by Chamberlin and others, particularly with reference to its bearing on glacial climates, and has involved new conceptions of the origin of the earth. But entirely apart from the possible validity of these reasonings, the researches have value in setting forth the changes to which the atmosphere is subject. These changes have so much to do with the earth's crust that they are germane to our theme.

It is shown that the atmosphere loses carbon dioxide in several ways; as through carbonation, that is, by the decomposition of silicates and the formation of carbonates of calcium and magnesium, in limestone and dolomites of great extent. This decomposition is extensive in times of elevation of the lands, such as have occurred widely in some geological periods. When the lands are high, the water table is farther below the surface, and the air pierces deeply, with its chemical activities, and the ground waters also have much more vigorous circulation. The carbon dioxide thus employed in making limestone is extracted from the atmosphere.

There is loss of carbon dioxide through fixation in coal, oil and in all organic matter, diffused through the sedimentary rocks. There is temporary loss of this gas through the ordinary feeding of plants, and the view has been held, that plant growth would exhaust the CO_2 of the atmosphere in one hundred years, but for the renewal through

[2] "Elementary Meteorology," W. M. Davis, p. 3.

plant decay and from other sources. All these processes would take from the air in geological time, many thousand times as much CO_2 as it now holds.

On the other hand, there have been gains through various sources of supply. These are, from the ocean, and from the interior of the earth by volcanic action, and in escape in connection with earthquake movements. Any changes involving deformation and fracture open the way for supplies of this gas from below. Van Hise lays emphasis on CO_2 as derived from volcanoes[3] and in the same passage refers to emanations from hot springs and mine waters. He quotes Lecoq to the effect that the mineral springs of the Auvergne alone give off nearly one tenth as much of this gas as is freed by the entire coal burning of Europe. The same author includes meteorites as a source of CO_2 but regards this means of gain as unimportant in later geological eras. Possible supplies may have been received from the sun, if the projection of gases from that body is sometimes so energetic as to shoot them within the orbit of our planet; and, as has been implied, there is a steady restoration of this gas through decomposition of organic matter, and through organic processes.

As oxygen combines actively with some substances, notably iron, we are to expect large losses of this gas from the atmosphere, when we remember that oxidation has been a world-wide process, throughout the history of land surfaces, down to the lowest level of atmospheric penetration. Thus Smyth concludes a brief essay on this subject by saying, "The abstraction of oxygen by iron is a factor that can not be disregarded in any attempt to work out the geological history of the atmosphere."[4]

There have also been compensating supplies of oxygen. The fixing of carbon in the crust involves the freeing of oxygen. There have been times of predominant plant life, leading to the abstraction of CO_2, and the release of O, thus notably changing the atmosphere until animal life enlarged its province, using O and freeing CO_2. Chamberlin thinks that organisms have freed more oxygen than the rocks have absorbed and that this gas therefore has had a growing part in the atmosphere.

Nitrogen, as is well known, is the inert part of our atmosphere, but is absorbed through certain bacteria, leading to modern effort to utilize it in restoring the fertility of the soil. On the other hand, some nitrogen is supplied to the atmosphere through volcanic eruptions.

These views of atmospheric inconstancy involve general doctrines of climate and earth history which are in the crucible of discussion. The efficiency of the atmosphere as a thermal blanket is held to be so dependent on the amount of carbon dioxide present, that moderate

[3] "Treatise on Metamorphism," pp. 969–970.

[4] "The Abstraction of Oxygen from the Atmosphere by Iron," C. H. Smyth, Jr., *Jour. Geol.*, 13, 319–323.

fluctuations in the quantity of this gas may go far to explain the noteworthy glacial episodes of later and earlier geological times, and those warm climates which at other periods have spread so widely over the earth.

Thus we have geographic hypotheses, and astronomic hypotheses, so it seems appropriate that we should have atmospheric hypotheses, in the laudable effort to understand and explain that great series of geologic climates, which may indeed seem remote, but with the latest of which, we should remember, we ourselves have to do.

Our interest in the evolution of the atmosphere and of climate is of no theoretical sort. We are not in the grip of forces which are in a despotic way our masters. We have a large control of organic life on the earth and of the disposition and character of all land waters. Through these means we also largely regulate the processes of denudation and we may thus in some measure modify the very constitution of the atmosphere. Van Hise, on what he regards as a moderate estimate of the coal the human race will burn per annum during the present century, estimates that in 812 years the amount of carbon dioxide in the atmosphere would be doubled.[5] According to the view of Arrhenius such a change would greatly ameliorate the climate of the world. This view of the heat-holding effects of an increase of CO_2 is not undisputed, but so large a change in the constitution of the atmosphere, by the hand of man himself, may well cause him to investigate, with serious persistence, the terrestrial consequences of his own deeds.

Van Hise has impressively set forth the work of man in lowering the level of the ground water. We do this by deforestation, by cultivation, by irrigation, by the sinking of artesian wells and by mining. For so many purposes man needs water, or needs to get rid of water, that actual and serious lowering of the water table has taken place, and will be brought about more and more with growing density of population. Lowering the ground water, as we have seen, increases the contact of the atmosphere with the rocks, and sets in motion a chain of actions which may have consequences for good or ill, quite outside our present knowledge and inviting expert investigation for many years to come. These considerations have a bearing, possibly an imminent bearing, upon all our conservation enterprises in the United States.

Scientific truth often gives us no inkling of astonishing practical results which are about to flow from it. Thus meteorology is no restricted theme for the curious. It is not merely a science of climate, though this would give it the highest interest for science and for life: it is profoundly related to the history of our planet and it is an essential part of physical, biological and human geography.

[5] "Treatise on Metamorphism," p. 464.

THE PALEONTOLOGIC RECORD

The Paleontological Society Conference Papers

By Professor JOHN M. CLARKE
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Introductory.—The birth of a new society devoted to special scientific aims counts but little for the advancement of knowledge and culture in these days of multiplex organizations if it fails to come into being and before the world with an adequate excuse and a clean-cut purpose. The Paleontological Society, which was conceived a year ago and born last winter in Boston at the meetings of the American Association, is the outcome of a conviction on the part of workers in this science that there is a common bond of interest among them all, in spite of the peculiar conditions which have stamped paleontology with their diversity and kept its devotees asunder. Students of this science have approached it along different avenues. Some, and chiefly those dealing with the vertebrates, have laid the foundations of their work in the living world; others, and here chiefly the students of invertebrates, have made their entry as geologists and have worked their way from beneath upward to the earth's surface. Among the paleobotanists good men have arrived through both approaches. As an equipment for trustworthy and lasting work, both of these lines of preparation have proved their efficiency and so all arguments bent to demonstrate the superiority of the one over the other schooling resolve themselves to a conclusion that both are essential to the best result.

Diversity in training and in the field of activity has led to diversity of sympathy, and it seemed, even to those who had long hoped for a unification of these interests, that it might hardly be practicable to obliterate these cleavage planes. The governing principles of the science are common, the bearings of paleontologic researches and results are the widest conceivable in their relation to the problems of life, whether past, present or future, and it is not likely that the magnitude of the science can be unduly stated. From some such considerations as these, the writer, chosen as first president of the new society, endeavored to bring into the foreground of the society's first meeting, by a "Conference on the Aspects of Paleontology," an introductory presentment of some of the broader factors and principles of the science, and the articles that follow herewith are the partial outcome of this conference. In every case where practicable, the themes were presented by two

speakers making their approach from different fields of interest. The conference was an effort to define and emphasize the common platform on which the paleontologists must stand together; even more than this, it was a purpose to declare at the outset that the organization, though the patron of detailed researches and patient endeavor, recognizes that the sole impulse which can guarantee its usefulness and maintain its integrity is its devotion to a standard which touches close on human interests.

ADEQUACY OF THE PALEONTOLOGIC RECORD

By Professor SAMUEL CALVIN
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WHEN or how life began on our planet no one may be able to tell us; but that life has been present and has been an important factor in the world's geological development since before the beginning of the Cambrian is known to the most callow of embryo geologists taking his first course at the village high school. So far as relates to the skeleton-bearing, marine invertebrates which have lived on floors of epicontinental seas, there are remarkably complete records of this long history of living things, the order of their succession, their migrations, their geographic distribution during any given portion of geologic time, as well as of the progressive and orderly modifications which resulted in the extermination of decadent or unfit types, on the one hand, or resulted, on the other hand, in the advancement of certain types and their adaptation to the conditions prevailing in the living world to-day.

The zoologist, confining attention to living forms, gets a view of the animal creation as it exists, after ages of development and modification, during a fraction of a single faunal stage. The paleontologist, while unable to see the beginnings of life, gets the broader view which comes from a study of the organic world as it has appeared during numberless successive stages. He may trace the origin of forms and note the trend and tendency of variations in ways denied the zoologist. Neither the depth of the water nor the distance from the shore at the points where the objects of his study lived interferes with the thoroughness of his explorations. He is not limited to what he may learn by taking samples of the old sea bottom, here and there, with a dredge; he traces his life zones with practical continuity over areas of continental extent.

The faithfulness with which the paleontological record has been kept since the beginning of the Cambrian is a matter of constant surprise. No organism was too small for preservation, if only its soft

parts were supported or protected by a stony skeleton of some kind; no parts of the skeletal structure were too minute to be kept practically unaltered to the smallest microscopic detail; no period of time has been so long that the records of the large or the small things of life were necessarily obliterated. The shells of such minute and delicate things as radiolaria and foraminifera, on the one hand, and that king of invertebrates, the giant *Camaroceras,* on the other, have all been kept through the ages with equal fidelity. The hinge characters of the brachiopods, their internal arm supports, their spires and loops, the distribution of the ramifying blood channels in the mantle, the surface markings of every rank and grade down to the smallest which can be observed only with the lens, and the microscopic structure of the shell itself, are other examples of the faithfulness with which details, however insignificant in point of magnitude, have been guarded, protected, preserved. Strangely enough, in respect to a very large proportion of the animal remains buried in the ancient sediments it looks as if time had been standing still; it has neither marred nor destroyed. The organic remains from the Ordovician formations are quite as perfectly preserved as those from the Tertiary.

The profusion of the life of the ancient seas is as much a source of surprise as the detailed perfection of the record. In the Mississippi Valley limestones constitute a very large proportion of the sedimentary rocks, and it is unnecessary to say that these limestones record the life and death of countless myriads of organisms. In some cases the waters of the old seas were comparatively quiet, and the shells or other hard parts, undisturbed and unbroken, remain in the positions they occupied when the individuals they represent were alive. There is a bed of marly shale carrying many thin lenses of limestone, lying between the Platteville and the Galena, from 60 to 70 feet above the base of the Mohawkian, and these lenses are made up in large part of unbroken brachiopod shells. On the surface of one of these slabs, in an area measuring 35 square inches, one may count more than 60 perfect specimens of *Dalmanella subæquata* and *Orthis tricenaria.* The rate is about 290 individuals to the square foot. The number on a square mile of such sea bottom runs up into the billions. The number of individuals of the species *Pentamerus oblongus* that swarmed on the bottom of the Niagaran sea is strikingly demonstrated in every paleontological museum. The wide geographic range of this species is well known; its range in time was such as to make possible the accumulation of beds of limestone, 70 feet in thickness, from the detritus of its broken shells. Like other persistent or widely ranging species, it gave rise to a very large number of varietal forms, some of which have been described as specifically distinct.

The Devonian formations furnish similar evidence of the wonder-

ful profusion of the ancient life and help us to appreciate the wealth of material that the paleontologist has at his command. In the quarries at Independence, Iowa, there are beds crowded with beautifully preserved forms, mostly brachiopods, as perfect to-day in every detail of shell structure and ornamentation as when the currents of life pulsated within. A coral reef, no species lost, has been cut into by a small intermittent stream near Littleton, Iowa; and perfect coralla, wagon loads of them, are strewn along the sandy channel a quarter of a mile or more. A successor to the reef just noted, composed of different species, the corals still in place, may be seen and studied on the west side of the river opposite the village of Littleton. The state quarry beds near North Liberty are simply cemented masses of brachiopods; they illustrate the remarkable prodigality of the Devonian life, but the individuals are not in good condition for study. It is a different case that is presented by the fossils in the marly beds of the Lime Creek shales at the exposures between Mason City and Rockford. A very large proportion of the specimens here are as perfect as when the animals lived; and there is a beauty and delicacy and exquisite refinement about most of them that is scarcely matched, certainly not surpassed, anywhere among fossils of any age or time. More than 65 species occur in the Lime Creek fauna, and thousands of individuals of some of the species, illustrating wide ranges of variation, enrich the museums of the world.

Along the Aux Sables River at many points near Thedford and Arkona, Ontario, there are calcareous shales containing a marine fauna, or rather a succession of faunas which once flourished in wonderful profusion and is still preserved in equally wonderful perfection. Statistics and computations would fail to give an adequate conception of the abundance and character of the material here offered for study. No detail of the skeletal parts has been lost; and as for the number of individuals, they are simply uncountable. There lies before me a small fragment of this old sediment having a surface of less than 15 square inches and it shows 51 identifiable individual specimens, not counting stem segments of crinoids. The 51 individuals are distributed among eleven species, and these represent eleven genera—namely, *Phacops, Platyceras, Tentaculites, Spirifer, Chonetes, Hederella, Orthopora, Chætetes, Arthracantha, Striatopora* and *Aulopora.* Can any bit of modern sea bottom of similar size make a better showing? Above and below the Rocky Glen, near Arkona, from which this specimen came, there are opportunities to study continuous sections approximately 100 feet in thickness, the successive beds crowded with organic remains and revealing the historic sequence of varying organic types as the life responded to slight changes of environment. Here, as at countless other localities, the paleontologist gets a view of

changes, of movements, of trend and tendency among living things ranging over a period of time equal to many millenniums.

Another life record of especial interest, typical of many scattered up and down the land areas of the globe, is furnished by the Osage division of the Mississippian at Burlington and Keokuk. Of one group of crinoids, the Camerata, these Mississippian limestones have yielded about 250 species, and of other groups a number about equally as great. The beauty and perfection of the individual specimens can be appreciated only by those who have had the good fortune to see the superb collections of Wachsmuth and Springer. Crinoids flourished here in such numbers that beds of limestone 150 feet in thickness are built practically of crinoidal remains and nothing else. The time represented was long enough to allow of a series of modifications of such extent that the crinoid fauna of the Upper Burlington is very distinct from that of the lower beds of the same formation, while the fauna of the Keokuk differs from both. Here again the paleontologist is favored, not only with a wealth of material, but with an opportunity to note the trend and tendency of things. This was the time of greatest development, of highest prosperity, among camerate crinoids. But in the midst of this prosperity the trained paleontologist may discover signs of degeneration, the prophecy of speedy extinction. The law enunciated by Beecher and quoted by Professor Woodward in his address before the geological section of the British Association at its meeting in Winnipeg last summer, is well exemplified in the Mississippian history of this particular group of crinoids. The tendency among any division of skeletal-bearing animals to run to extravagant ornamentation in the way of ribs, nodes, spines or other excesses of dead, useless, skeletal matter, is something that precedes and presages the decline and death of the race. Even in the Upper Burlington the skeleton of the crinoids is heavier than in the Lower; stronger nodes on the plates are produced; more arm plates are incorporated in the dorsal cup; the animals are weighted down with useless matter. This tendency is carried to extremes in the Keokuk limestone, a fact well exemplified by the species figured on plate 15 of Hall's "Geology of Iowa," Volume I., part II. In these species the development of massive spines and heavy nodose plates reaches its maximum. The race has come to the end of its career. When the Keokuk closes, only a few of the simpler forms of the Camerata survive, and even these shortly disappear. The paleontologist sees the operation of the same law, the same trend and tendency, among the Cretaceous Ammonoids; in many other groups of animals it is as clearly manifest; but it would not be profitable, before such a body as this, to carry the discussion farther, even if the limits of the paper permitted. Let me close by

quoting from the address of Professor Woodward, to which reference has already been made:

> Geology and paleontology in the past have furnished some of the grandest contributions to our knowledge of the world of life; they have revealed hidden meanings which no study of the existing world could even suggest; and they have started lines of inquiry which the student of living plants and animals alone would scarcely have suspected to be profitable.

ADEQUACY OF THE PALEONTOLOGIC RECORD

By R. S. BASSLER
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THE imperfection or inadequacy, instead of the adequacy of the paleontologic record, has long been a favorite subject of discussion, and it is only within recent years that this heresy of an imperfect record is being abandoned by paleontologists in general. However, as many of our biologic, and even a few of our paleontologic, friends still have doubts regarding the matter, the present conference upon this and allied subjects is very opportune.

I have a vivid recollection of the joy experienced in my school days, when, during an examination in geology, the subject of an impromptu essay was announced as "The Imperfection of the Paleontologic Record." Here was a subject in which I was well grounded from text-book reading, and I remember distinctly the telling points made. The lack of hard parts causing the absence of many classes of animals; the great amount of unrepresented time in the geologic column; the metamorphism and consequent disappearance of fossils, and, when present, the frequent imperfectness of the specimens themselves, were dwelt on in great detail. Since that time, my experience in invertebrate paleontology has compelled me to unlearn every one of these supposed facts, and to come to the conclusion that, considered both biologically and stratigraphically, the paleontologic record is sufficiently adequate for all reasonable purposes.

Professor Calvin's paper tells us (1) of the detailed perfection of the record, (2) of the profusion of the material, and (3) of the broad view as to trend and tendency of biologic characters which the study of paleontology gives. His presentation of the subject is such that we must all agree with him. It therefore seems best for me to confine my remarks to the reasons usually advocated for the imperfection, namely, the lack of hard parts in many animals, metamorphism, the frequent imperfect preservation of fossils, and the unrepresented time in the geologic column.

The lack of hard parts in many animals is a serious, although not fatal, objection to their preservation as fossils. For the best results as

fossils, a stony framework of some kind is desirable, as we all know, but horny, or even the most perishable materials may be preserved under favorable conditions. Mr. Walcott's work on the Medusæ, and the researches of Ruedemann on the graptolites, as well as the work of others whom we can call to mind, are examples of excellent results from material of the latter nature, not to mention the hairs of the worm so carefully described by the Cincinnati paleontologist!

The metamorphism and apparently complete obliteration of all fossil remains in the rocks of certain large areas is likewise an apparently serious objection to the adequacy of the record, but here careful searching with the structural relations in mind will reveal the fossils, if present at all. The greatly folded and cleaved slates, schists and volcanic tuffs of the Piedmont area have long been the despair of both paleontologist and geologist, but at this meeting of the Geological Society of America, the State Geologist of Virginia will tell of Cincinnatian fossils in the so-called Algonkian and other schists and volcanics of the easternmost Piedmont of that state. In this case the discovery of well-preserved fossils was quite simple. It consisted merely in finding a place where the cleavage and stratification coincided, and then working hard.

Professor Calvin has spoken of the richness and beautiful preservation of certain Paleozoic faunas. While the beauty and occasional richness of such faunas is not to be gainsaid, we must not forget the many horizons and localities affording, in comparison, specimens so poorly preserved that they might readily furnish an argument for the inadequacy of the record. Nor must we forget that in quite a portion of the geologic column organic remains are not only poorly preserved, but are, as known at present, very rare. However, these lean spots can be made most productive of paleontologic results by careful search and by methods of preparation. Several years ago the number of lower Paleozoic fossils found in the Ozarks could almost be counted on one's fingers, but we now have in the National Museum, from this formerly almost barren spot, several hundred drawers of beautiful material.

Fortunately the preparation and methods of study of paleontologic material has progressed to such a point that a poor fossil is no longer a bugbear. A specimen may be considered inadequate for study because it is covered with refractory clay. The application of caustic potash solves this difficulty. Certain limestone bands in the New York Niagaran and Cayugan are crowded with fossils, although often few of the species can be determined because of a hard, clayey covering. In preparing some specimens for exhibition, the treatment with caustic of a single slab, about three inches wide and five inches long, enabled me to bring out over a hundred species on one surface alone, not including the ostracods and other microscopic organisms. How often will the present sea bottom furnish such results?

Nature is very kind in preparing fossils for us. The Onondaga limestone, at the Falls of the Ohio, although only a few feet in thickness, has yielded seven hundred or more species of exquisitely preserved fossils. Examine the freshly quarried limestone and you may be able to crack out perhaps two dozen species of poorly preserved material, but go to the neighboring field where solution of the limestone and silicification of its contained fossils has occurred, and a host of beautiful forms awaits you. Strata, which under ordinary circumstances would yield very poor fossils, can, if silicification has commenced, be made to afford excellent specimens. By exposure to the weather for a year or so, the silicification can be advanced to such a stage that etching with acid will free the fossils. The beautiful etched material from the New Scotland of New York is a familiar example of this style of preparatory work. Most of the Cambrian and Ordovician formations of the Appalachian Valley yield shells which, as they occur in the limestone, are almost impossible as subjects for study, but as silicified pseudomorphs, all the beauty and detail of the original shell are reproduced.

Thin sections are a valuable aid in identifying the merest fragment of certain classes of organisms, and their use here is indispensable. A thin section of an otherwise undeterminable fragment of a Cambrian protremate brachiopod will distinguish the horizon. Other methods of preparation and study might be mentioned, but time forbids, although I can not refrain from speaking of the several whitening processes. The use of a coating of ammonium chloride or anilin chloride on fossils for photographic purposes is well known, but the excellent results obtained from the use of the same process in the study of poor material may not be so apparent to all. A trilobite indistinctly outlined in the rock under ordinary circumstances, flashes into bold relief when covered with the ivory white film of ammonium chloride. Casts and molds of fossils too indistinct to show any structure ordinarily, will reveal many characters when so whitened. Recently occasion arose to study a species of Cambrian phyllopod which had already been described and figured. The specimen was practically nothing but a film upon the rock, and apparently the last word had been said upon it. It was suggested that the specimen be whitened and then photographed with the sun's rays nearly parallel to its surface. The result was most gratifying as structures which could not be proved to exist by the aid of the eye alone, came into plain view in the negative. All these various methods of preparation and study make available a vast amount of material which formerly was thought too imperfect to be fully considered in determining the adequacy of the record, hence the great value of such methods to the paleontologist is obvious.

The real adequacy of the record, if it might be so called, lies in the

imperfections or gaps in the stratigraphic column. Measured according to the sections of twenty-five years ago, the number of these gaps is growing greater and greater, yet with the discovery and intercalation of new formations, the aggregate of which at the present day has almost doubled the thickness of Paleozoic rocks in the last decade, manifestly the great breaks are being reduced. It was not so many years ago that the Potsdam sandstone was supposed to be the oldest fossiliferous sedimentary rock, yet now we know that many thousands of feet of much more highly fossiliferous strata intervene between this formation and the Azoic, and that other thousands occur above the Potsdam and below the Ordovician as then recognized.

With the intercalation of new formations and the consequent diminution in the size of the stratigraphic gaps, it is then probably only a matter of time before the complete faunal succession can be established. The break in stratigraphy at one point will be bridged over in another area, and it is possible that in only a few regions, such as on the borders of the continent, will permanent gaps exist. Faunas are and will be traced from one area to another until in time we shall know their complete geologic history. With these data in hand, the study of their correlation will not only be greatly simplified, but also will not be hampered by time breaks in the record. While imperfect, or possibly irretrievably lost at the dawn, the faunas of succeeding times are ample for all purposes.

INTERDEPENDENCE OF STRATIGRAPHY AND PALEONTOLOGY

By Dr. W. J. SINCLAIR
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IN discussing this subject from the view-point of a vertebrate paleontologist, I am disposed to lay stress on what I believe ought to be, rather than what has been, the degree of interpendence of these two branches of geology. Vertebrate paleontology has been studied very largely from the morphological and genealogical side, a study of structure, adaptation and the evolution of phyla. Stratigraphic geology has been invoked only when it became necessary to know the order of superposition of the various horizons, to determine the true evolutionary succession of a phylum or development of an adaptation.

I have purposely presented this extreme view, not because I believe that such studies may not be classed legitimately as paleontological, but because I wish to emphasize, by contrast, the view-point which we should ever keep before us as paleontologists—the use of our materials as *Leitfossilien*. The two correlative conceptions of the faunal unit and the zone, a more or less restricted association of animals and the

rock layer in which it occurs and which it characterizes, long and successfully employed by the invertebrate paleontologist, must be recognized and used by us also.

I need hardly refer to the fact that the determination of the geological age and the successful correlation of many North American formations, ranging from Mesozoic to Pleistocene, depend in large measure, if not entirely, on vertebrate fossils. I need only contrast the American series of Pleistocene glacial and interglacial stages, determinable at present only by the strictly stratigraphic method of superposition, with the carefully worked-out series in Europe, where each epoch of ice advance and retreat is characterized by its particular fauna and flora. That even the beginnings of stratigraphic paleontology, as contrasted with the morphological, will lead to immediate and valuable results, is strikingly shown by Professor Calvin's[1] recent paper in the *Bulletin* of our parent society, the Geological Society, in which he describes the Aftonian mammal fauna from the earliest of American interglacial stages.

While readily admitting that the slow-moving invertebrate, living, it may be, in the very mud which is destined to become the matrix of its fossil remains, enjoys advantages as a prospective horizon-determiner which the agile vertebrate can more readily, and does most willingly, escape, still the short life of vertebrate species, and their comparatively rapid evolution, fit them for use as index fossils quite admirably. The localization of mammalian faunas, their inability to cross barriers such as ocean basins and great mountain ranges, their dependence on temperature, etc., are comparable to similar conditions circumscribing the free migration of invertebrates. We should not expect to find in the distribution of vertebrate faunas the analogues of the cosmopolitan graptolite zones of the Ordovician or the ammonite zones of the Trias, but we can work out our major zones as recognized by the great migrational movements among vertebrates, expressed in changes in the faunas and the rock succession, which will give us a world scale, and then, by interpolation, fill in the minor and local subdivisions which we probably shall not be able to correlate at once, but which there is every reason to believe we may be able to do later.

The attempt will be accompanied by difficulties which are not appreciated by the invertebrate paleontologist, and I speak feelingly and from experience, for there is a difference between collecting, on the one hand, from a layer a few inches thick, crowded with shells, and, on the other, tramping miles up hill and down over beds hundreds of feet thick, to be rewarded by a few teeth, a lot of useless bone fragments or nothing. Horizons based on vertebrates must include larger stratigraphic units

[1] *Bulletin of the Geological Society of America*, Vol. 20, pp. 341–356, Pls. 16–27, October, 1909.

than are recognized for invertebrates, because of the scattered nature of the material and the additional probability that continental deposits, in which alone vertebrates have their chief importance as guide fossils, have accumulated more rapidly than marine beds. Similarly, conditions peculiar to their mode of deposition make it difficult, perhaps impossible, to define lithologically the limits of the zones we are attempting to characterize. And here another trouble confronts us, for the faunas are incompletely known, and we are not yet in a position to dogmatize too freely on the subject of vertebrate index fossils. But that the method of zonal studies is the correct one is very clearly shown in Dr. Matthew's[2] recent monograph on the Carnivora and Insectivora of the Bridger Eocene, and will be demonstrated with equal force when Professor Osborn's volume on the titanotheres is published.

Various attempts have been made at the correlation of European and American mammal horizons, their measure of success depending entirely on the degree of closeness with which these correspond to true zones. At present, we are attempting to correlate subdivisions, both faunal and stratigraphic, of all orders of magnitude, the majority including many faunules and many zones. Evidently, this tendency must be corrected by careful zonal studies, if vertebrate paleontology is to have any standing as an aid to stratigraphy in the correlation of our non-marine formations.

BIOLOGIC PRINCIPLES OF PALEOGEOGRAPHY

By Professor CHARLES SCHUCHERT
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IN deciphering the ancient geography as to the position of the marine waters and the land masses, we as pioneers in this work must be controlled primarily by the known fossilized life and secondarily by the character and place of deposition of the geologic formations. This record is most extensive and best preserved in the deposits of the continental and the littoral region along the continental shelves of the oceanic areas. Back of these two principles, however, there is another that eventually will become the primary guiding factor. It is the principle of diastrophism—one seeking to explain the causes for the periodic movements of the lithosphere.

In our study of the ancient seas with their sediments and entombed life we have safe guidance in the phenomena of the present. Ludwig in 1886 estimated the species of animals then known to naturalists as upwards of 312,000, and in 1905 Stiles thought this great total had increased to about 470,000 forms. Of this sum fully 60 per cent. are insects, and of the remainder, the writer concludes that about 25 per

[2] *Memoirs American Museum of Natural History*, Vol. IX., Part VI., 1909.

cent., or 115,000 species, live in the sea, and 71,000 have their habitat on the land or in the waters of the land. Of the 115,000 kinds of known animals inhabiting the seas nearly 70 per cent. are Cœlenterata, Echinodermata, Molluscoidea and Mollusca, the types of organisms most often found by the stratigrapher and on which he is largely dependent in deciphering the ancient geography.

Let us now examine into the number of available fossil forms made known by the paleontologists. As early as 1868, Bigsby in his "Thesaurus Siluricus" listed 8,897 species from the strata beneath the Devonic, and in his "Thesaurus Devonico-Carboniferous" of 1878, he further enumerated about 5,600 Devonic and 8,700 Carbonic forms. In 1889 Neumayr concluded that there were then known about 10,000 Jurassic species. We may therefore estimate that the paleontologists of to-day have access to at least 100,000 species of fossils. Their numbers in the geologic scale are about as follows: Cambric 2,000, Ordovicic 8,000, Siluric 8,000, Devonic 9,000, Lower Carbonic 7,000, Upper Carbonic 8,000, Permic 4,000, Triassic 6,000, Jurassic 15,000, Cretacic 10,000 and Tertiary 25,000. The end of species-making is not at all in sight, and the day will come when paleontologists will deal with ten times as many species as are now known.

Stiles tells us that zoologists know but from 10 to 20 per cent. of the living forms, and there should therefore be from 3,760,000 to 4,700,000 different kinds of animals alive to-day, ranging from the protozoa to man. Now let us compare the abundance of living animals with those of the geologic ages, and especially with the Jurassic period, of which life we have probably a better knowledge than of any time back of the Tertiary. The European Jurassic has long been divided into 33 zones (Buckman hints at a probable 100), and if we hold that each one of these times had only one quarter as many species as in the lowest estimate of the present world, there must have lived during the entire Jurassic something like 31,000,000 kinds of animals. Yet paleontologists have described not more than 15,000 Jurassic forms. The great imperfection of the extinct life record is thus forcibly brought to our attention, and we learn from these estimates that for each kind of animal preserved in the rocks more than 2,000 other kinds are utterly blotted out of the geologic record.

Much of this more apparent than real imperfection, however, is due to the vast number of insect species now living—animals that must have been comparatively few in the Jurassic, due in the main to the absence of flowering plants. From these figures, however, we must not conclude that the geologic record is equally imperfect throughout; for the paleontologist studying marine fossils well knows that he can not, as a rule, hope to study other than those kinds of animals that have hard and calcareous or siliceous external or internal skeletons. Of

such there may be in the present seas about 250,000 kinds, of which about 25,000 have been named. Therefore on this basis we can say that the student of Jurassic faunas knows 1 species in every 54 of shelled animals that lived during this period.

This admittedly great imperfection of the life record needs to be further explained so that the reader will not arrive at the erroneous conclusion that modern stratigraphy rests upon very insecure foundations. The stratigrapher in determining the age of a given deposit, and in the identification of it from place to place and from country to country, and even across the great oceans, deals in his work not with quantity of species, but with comparatively small numbers of constantly recurring hard parts of certain species that are more often of marine than of land origin. Many of these forms have but local value but others have spread thousands of miles, and some of the long enduring species range over the greater part of the earth. Some of the best guide fossils in the Paleozoic are the brachiopods because they are present in nearly all the strata of this era. The writer in 1897 listed 1,859 forms then known from these rocks of North America. Of these about 28 per cent., or 537 species, had great geographic distribution. 117 species are found in the Rocky Mountain area, the Mississippi valley and the Appalachian region, and of these 36 are also known to occur in foreign countries. The number of species common to North America and other continents, however, is 121. It is upon faunal assemblages of this quantity and nature that the stratigrapher relies most in deciphering the former extent of the continental seas.

In the making of paleogeographic maps or in the determination of geologic time, using fossils as the essential basis, we have guidance in those of marine faunas, and the floras and faunas of the land and its fresh waters. Of these widely differing realms or habitats we now know that the fossils of the marine faunas are the more reliable not only because there are so many more of them than of the land dwellers, but more especially because their geologic succession is far more complete. The conditions of preservation, that is, appropriate burial in sediments, are always at hand in marine waters, but on the land entombment occurs only exceptionally, whereas the life of fresh waters is very meager and almost unchanging during geologic time. Then, too, marine life is "less affected by meteorologic factors, and more dependent upon conditions which affect the whole hydrosphere rather than small areas of it. The struggle for life is less intense, the food supply generally more adequate, enemies less vigorous, and dangerous fluctuations of temperature far less frequent, in the sea than on land. The same features make the land fauna more clearly indicative of minor divisions of the scale, and of the progress of organic evolution

in the general region concerned; while less conclusive as to the contemporaneity of widely separated though analogous faunas."[1]

In regard to the probable geographic position of the shore lines we rarely have safe guidance in the fossils, and for this depend on the nature of the deposits. Greatest dependence is placed upon the geographic position of sandstones and especially on conglomerates to indicate the probable former shores. Limestones of uniform character and wide distribution are indicative of greater distance from land. Shallowness of the continental seas is proved by a rapid change in the character of the sediments both laterally and vertically, and by the oolite and dolomite deposits. Intraformational conglomerates, coral reefs, ripple marks, and shrinkage cracking furnish further evidence to the same conclusion. Storm waves are known to plough the present sea-bottom to depths of 160 feet. Calcareous muds are now forming in tropical and subtropical waters at sea-level around coral reefs, and elsewhere in these latitudes at depths from 200 to 600 meters. It is probable that all of the ancient great limestone deposits are of warm waters, and, if so, are an additional aid in discerning the geologic times and regions of milder climates.

Phosphatic concretions form in the littoral region where the temperature changes are rapid, as off the coast of the New England states, and periodically cause much destruction of the individual life. The carcasses decompose at the bottom of the sea, making nuclei for the accretion of phosphate of lime, and because of the irregular periodicity of accumulation come to be arranged in definite stratigraphic zones. Old Red sandstone fishes are also usually found in clay nodules but abundantly only in limited zones (Scaumenac, Canada and Wildungen, Germany). Have these also been killed by rapid changes in the temperature of these waters? In any event the fish-bearing beds are always found near the shore lines of Devonic seas.

Scour of sea bottom is met with in the present seas where great streams of water are forced through narrow passages, as the Gulf Stream in the Floridian area; or where such streams impinge against the continental shelf, as north of Cape Hatteras, or flow across submerged barriers "a few miles broad," as the Wyville-Thomson ridge connecting the British and Faeroese plateaus (Johnstone, 1908, 31). Strong currents preventing sedimentation also occur in long and narrow bays, as that of Fundy, where the undertow caused by the very high tides of this region sweeps the bottom clean. These exceptional and, after all is said, rather local occurrences can not be the explanation for the many known breaks in the geological sedimentary record, the disconformities of stratigraphers. These breaks are at times as extensive as the North American continent (post Utica break), and are usually

[1] Dall, *Jour. Geol.*, 1909, 494.

of very wide extent. Scour of the bottom by the currents of the ancient continental seas will not explain away the presence of these truly land times, but it is to be sought in the oscillatory nature of the seas of all time which is probably caused by the periodic unrest of the earth's crust due to earth shrinkage. We agree with Suess that "Every grain of sand which sinks to the bottom of the sea expels, to however trifling a degree, the ocean from its bed," and every movement of the sea-bottoms and the periodic down fracturing of the horsts causes the strand lines to tremble in and out, be they of a positive or transgressive or of a negative or land-making character.

The ancient marine life had similar zoogeographic arrangement to that of the present. It can be grouped into local faunas and these combined into subprovinces, provinces and realms. Their distribution is governed primarily by the presence or absence of land barriers, and secondarily by temperature and latitude. In the present seas temperature is one of the main factors controlling the distribution of the species, but during the geologic ages the climate was, as a rule, far more uniform than now, as we are living under the influence of polar ice caps and a passing glacial period, or possibly even an Interglacial period.

The faunas with which the stratigraphic paleontologist works appear in many instances as suddenly introduced biotas. Our collaborators of half a century ago explained them as Special Creations, but since their time we have learned that the suddenly appearing faunas are not such in reality but only seem to appear rather quickly due to the slowness of sedimentary accumulation. Ulrich estimates that the American Paleozoic has less than 100 mapable units or formations, each with a duration of probably not less than 175,000 years. Accordingly, each foot of average sedimentary rock has taken not less than 833 years to accumulate. Our knowledge regarding the average rate of sedimentary marine accumulation is, however, as yet very insecure, and to make this clear some of the remarks made by Sollas, President of the Geological Society of London (1910), will be quoted. He was led to make these remarks after the reading of a paper by Buckman correlating the Jurassic sections of South Dorset. He said, "The correlation of thin seams with thick deposits was a matter of great importance. . . . It might afford some hints as to the order of magnitude of the scale of time. If we assumed that one foot of sediment might accumulate in a century, in an area of maximum deposition, then in the case of the seam two inches thick, which was represented by 250 feet in the Cotteswolds, the rate of formation would be less probably than 1 foot in 150,000 years." What Ulrich's estimate of time necessary for the accumulation of one foot of average sediment means to migratory faunas may be illustrated by the spreading of *Littorina littorea*. In the last

century this edible European gastropod was introduced at Halifax, Nova Scotia, and in 50 years attained the Delaware Bay and north to Labrador. Taking this dispersion as the basis for calculating faunal migrations, we learn that they may spread 500 miles, while one sixteenth of an inch of average sediment is depositing, or 8,000 miles during the time of one foot of sedimentary accumulation. If, therefore, Paleozoic faunas migrated "only one fiftieth as fast as this living shell, then we may reasonably assert essential contemporaneity for stratigraphic correlations extending entirely across the continent." We have here an explanation for the apparently sudden distribution of the Ordovicic brachipod *Rhynchotrema capax,* that everywhere holds an identical geologic horizon from Anticosti to the Big Horns and from El Paso, Texas, to Arctic Alaska. *Spirifer hungerfordi* spreads during the first half of Upper Devonic time from the Urals to Iowa, and another brachiopod, *Stringocephalus burtoni,* migrates during the last third of Middle Devonic time from western Europe to Manitoba.

The life of the present seas extends from the strand-line to the deepest abyss, but by far the greatest quantity and variety lives in the upper sunlight, photic or diaphanous region. Photographically the light of the sun is detectable in exceptionally clear-water tropical seas to a depth of about 2,000 feet, but Johnstone places the average depth for all waters at 650 feet, beyond which there is more or less of total darkness, the aphotic realm.

Sunlight is the first essential for the existence of life. Where it penetrates, there plant life is possible, and this life is the substratum on which all animal life is ultimately dependent for food. Near the surface of the sea lives the plankton, sometimes referred to as the "pastures of the sea" and compared with the "grass of the fields." Most of this plankton consists of diatoms that at present are by far more prolific in the cooler polar waters. At times of greatest abundance in Kiel Bay as many as 200 of these "jewels of the plant world" are contained in a drop of water, and in the Antarctic seas there is an area of ten and one half million square miles where diatom ooze is accumulating. They are the principal food supply for most of the sessile benthos, or bottom life, among which the mollusca and brachiopods are of the greatest importance in paleogeography.

Geologic deposits rich in diatoms are sometimes regarded as those of the deep sea, at least as of deeper waters than those of continental seas. The English Carbonic deposits, rich in diatoms, have a fauna whose species are all of the shallow water kinds. The vast Miocene diatom deposits of California, described by Arnold, have living bottom types of foraminifera that, according to Bagg, do not indicate a depth of over 500 fathoms.

From the present distribution of marine life we learn that the

greatest bulk of invertebrates are restricted to the bottom of the shallow seas within the depth to which sunlight readily penetrates, that is, a depth on the average not over 600 feet. The value of this observation to the paleogeographer and the student of fossil marine life lies in the confirmation of paleontologists that continental seas are shallow seas, to the bottom of which in most places sunlight permeates. These seas are to be compared with the littoral regions of the present oceans, and they are the areas that are most exposed to climatic and physical changes, due to their proximity to the atmosphere and the lands. The life of these waters is, therefore, subject to an environment that is more or less changeable, and one of the basic causes underlying organic change. It is the invertebrates of the littoral and shallow seas that the paleontologist studies.

In the tropical and subtropical shallow seas one meets with the greatest variety of life and with the brighter colored and more ornamental shelled animals, but we are much surprised when told that the greatest number of individuals occur in the colder shallow waters of the temperate and polar regions. Johnstone states, "There is little doubt that the distribution of life in the sea is exactly opposite to that on the land. The greatest fisheries are those of the temperate and arctic seas. . . . Nowhere are sea birds so numerous as in polar waters. The benthic fauna and flora are also most luxuriant." The Bay of Naples has a "richly varied, but (in mass) a scanty fauna and flora," and "at the very least the amount of life in polar seas is not less than in the tropics."[2]

Marine life is also more prolific near river mouths of the temperate zones, probably because of the great quantities of dissolved "salts of nitrous and nitric acid and ammonia, and other substances which are the ultimate food-stuffs of the plankton." Just outside of the estuary of the Mersey in Lancashire there were "not less than twenty, and not more than two hundred animals varying in size from an amphipod (one fourth inch long) to a plaice (eight to ten inches long) on every square meter of bottom" (Johnstone, 1909: 149, 176, 195–6). Finally the quantity of life in the shallow waters of the sea is not directly governed by favorable habitat, such as shallow sunlight waters in constant circulation and of equable temperature, but seems to be primarily controlled by the amount of the minimal food elements. Sea-water may be regarded as a dilute food-solution having the essential materials on which life is dependent. Of these nitrogen and the compounds of silica and phosphoric acid are present in the smallest amount. Johnstone tells us that "The density of the marine plants will therefore fluctuate according to the proportions of these indispensable food-stuffs" (234). "It is only the protophyta among the

[2] "Life in the Sea," 1908, 201–205.

plankton which can utilize the CO_2 and the nitric acid compounds, and so we see that upon these rest the greater part of the task of elaborating the dissolved food-stuff of the sea" (239).

Undoubtedly much of the land-derived nitrogen, estimated at 38 million tons per annum, is used up in the shallow areas by the plants. We therefore arrive at the conclusion that shallow seas bordering naked, cold, or arid lands should have the smallest amount of life, and that those of temperate regions adjacent to low lands under pluvial climates should have the greatest number of individuals. This conclusion, however, may be decidedly altered by the oceanic currents in that they distribute far and wide the salts of the sea.

These factors also suggest that during "critical periods" the faunas should be least abundant and varied, and that at the times of extreme base levels and sea transgressions they ought to be at their maximum development. These suggestions are borne out by the small Cambric, Permic and earliest Eocene faunas and the large cosmopolitan biotas of the Siluric, Jurassic and Oligocene times.

Sessile algæ are not common on muddy or sandy grounds, and these areas in the present seas have been compared with the desert areas of the lands. That muddy grounds are now nearly devoid of algous growth has particular significance in stratigraphy, because in the geologic column at many levels and in nearly all regions occur black shale formations that are not only devoid of plant fragments but are also usually very poor in fossils of the sessile benthos. When the latter are present it is seen that they are usually thin-shelled and small forms, or are types of organisms that live in the upper sunlight realm and are either of the swimming plankton or the floating nekton. As examples of such deposits may be cited the widely distributed Utica formation of the Ordovicic extending from southern Ohio to Lake Huron and east to Montreal, and the Genesee (Devonic) of New York. In these cases what appears to be of the sessile benthos is thought to belong to the nekton attached to floating seaweeds or other floating objects, and eventually all of the life of the nekton and the plankton sinks to the bottom of the sea. Therefore the carbonaceous matter of the black shales may be of algous origin like that of the New York Genesee, but it is far more probable that it is largely of animal origin, as the crude petroleum of such deposits usually has the optical properties of animal oil and especially those of fish oil.[3] Plants may be torn from rocky bottoms of the shallow areas by the action of the storms and then carried by the currents into eddying areas like the present Sargossa Sea, which has among its algæ a very characteristic assemblage of animals. It is probable, however, that black shales having wide distribution were more often the deposits in closed arms of the sea (cul

[3] Dalton, *Economic Geology*, 1909, 627.

de sacs), or when of small areal extent, as the result of fillings of holes in the sea bottom. In all such places there is defective circulation and lack of oxygen resulting in foul asphixiating bottoms.

These are the "halistas" of Walther and the "dead grounds" of Johnstone. To-day such are the Black Sea and the Bay of Kiel, where sulphur bacteria abound in greatest profusion. These decompose the dead organisms that rain from the photic region into such suffocating areas, or the carcasses which are drawn there by the slow undertow from the higher ground. These bacteria in the transforming process deposit in their cells sulphur that ultimately combines with the iron that is present and replaces the calcareous skeletons of invertebrates by iron pyrite or marcasite. In this way are formed the wonderfully interesting pseudomorphs of *Triarthrus becki*, the Utica trilobite preserving the entire ventral limbs, and of the other well preserved but small invertebrates from the Coal Measures black shale of Danville, Illinois.

Brackish-water and especially deep-sea shelled animals tend to have thin shells, while increase of salinity tends towards the thickening and roughening of the calcareous shells. It is a well known fact that in the dolomite-depositing continental seas like that of the Guelph (Siluric), all of the molluscs have ponderous thick shells. These have been interpreted as reef-living species but actual reefs in the Guelph are unknown. The molluscs are often common but corals are represented by but a few species. Similar conditions are known to occur in other dolomite faunas. Further, the Guelph was of a time of decided progressive emergence and restrictional seas under an arid climate, and therefore the waters must have been abnormally salty.

Rivers constantly discharge into the sea great quantities of plant material, but as a rule little of it other than the wood is swept far out to sea. At present the rivers of northern Siberia float into the sea vast numbers of logs that drift with the currents to Spitzbergen, East and West Greenland and Arctic America. This wide dispersal of wood by the sea is met with only in the cold regions, whereas in tropical waters the wood is rapidly decomposed. Single leaves are rarely transported far from their place of origin, and when of good preservation in geologic deposits, give decisive evidence of the nearness of the shore. On the other hand, tough palm leaves have been seen in the sea 70 miles from land and rafts of leaves are often met with 200 or more miles beyond the mouths of the Kongo and the Amazon. Proximity to shore is also indicated by the presence in marine faunas of land molluscs, insects and bones of land vertebrates.

With tillites now known in the Lower Huronian of Canada, in the Lower Cambric of northern Norway, China, South Africa and Australia, and in the Permic of India, South Africa, Australia and Brazil, we observe the recurrence of glacial climates. The Siluric and Devonic

coral reefs occurring in Arctic regions, the sponge, coral and bryozoa reefs in the Jurassic of northern Europe, the rudistid and other cemented pelecypods in reefs of wide distribution in the Cretaceous, and the almost world-wide distribution of the Nummulitidæ (north of Siberia) in the late Eocene and Oligocene point as clearly to warm waters and mild polar climates. Further the widely distributed Carbonic foraminifers of the family Fusulinidæ that swarmed in temperate and tropical regions are unknown to Arctic and Antarctic regions. In other words, long before we have a fossil record the earth had climatic zones, and for long periods the climate was mild to warm, punctuated by shorter intervals of cold to mild climates.

The volume of sea water to-day is very great, but we must ask ourselves: Has this quantity always been such or was it even greater, as some geologists still hold? We no longer agree with Laplace and Dana that the earth passed through an astral stage, but rather agree with Chamberlin that it always has had a more or less cold exterior. Through volcanic activity much juvenile water from the interior of the earth was extruded in geologic time and was added to the vadose waters of the surface. Suess states that "the body of the earth has given forth its oceans and is in the middle phase of its gas liberations." Accordingly, the Paleozoic oceans must have been quantitatively smaller than those of the present, and the gradual increase in the volume of vadose waters has been accommodated by the periodic increase of oceanic depth.

We also agree with Walther that the oceans of Paleozoic and earlier time did not have the great abyssal depths they now have. The accentuated deepening of the permanent oceanic basins did not begin until the Triassic, for in none of the great depths of the present oceans are found traces of Paleozoic organisms, and all here are of Mesozoic or Tertiary origin. In the shallow regions, however, are still found a few Paleozoic testaceous-bearing genera of brachiopods, tubicular annelids, pelecypods, gastropods, *Nautilus,* and *Limulus.* The deepening of the Pacific, the Indian, and especially the Atlantic oceans has been at the expense of the lands or horsts, for the ancient continents, Gondwana and Laurentia, have each towards the close of the Mesozoic been broken into several masses. We may therefore speak of permanent oceans, and transgressed, fractured, and partially down faulted, continents or horsts.

These are some of the factors that control the making of some of the modern paleogeographic maps.

BIOLOGIC PRINCIPLES OF PALEOGEOGRAPHY

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CONSIDERING the breadth and intricacy of the subject assigned me, and the limited time that can be given to its consideration, it has seemed best to me to restrict my remarks to two or three of the obviously more important phases of the problem.

Aside from the study of the rock-masses themselves—which are often difficult of interpretation—reliance for an interpretation of paleogeography must be placed in the former life found entombed, and of the two biologic elements, plants undoubtedly hold a very high—probably the highest—place.

In making use of plants in the study of paleogeography we may first consider distribution. If we find two fossil floras identical or similar in all essential or important details, we feel justified in regarding them for all practical geologic purposes as contemporaneous. In order that we may be certain that the two floras are identical, they must be composed of types that are readily identifiable, that is, forms so well characterized that they may be easily and certainly recognized. As examples of such floral elements mention may be made of many ferns and fern allies, most cycads, conifers and peculiar, well-marked or characteristic dicotyledons. Having settled the contemporaneity of the floras, inquiry may next be made as to the probable manner in which the separated or isolated areas were reached by these floras. Here again we must carefully consider the character of the flora and the means for its natural dispersal. The living flora, and for that matter probably the floras from at least the beginning of the Tertiary progressively to the present time, has developed in many ways means for the comparatively rapid and wide-spread dissemination of their reproductive parts (seeds, etc.). For example, a large percentage of the members of the dominant living family of seed-plants—the Compositæ—have developed seeds with an attachment of soft, fluffy hairs which serve to float them in the air, often to great distances. In many other living groups there are similar, or at least as effective, devices for dissemination, but as we go back in time adaptations calculated to be of aid in distribution grow less and less, and soon even seeds of any kind are unknown, or known but imperfectly, and reproduction is normally by means of spores, that is, reproductive bodies in which there is no embryo already formed when they leave the parent plant. It is obvious that plants that are reproduced by seeds, in which there is both an embryo and a supply of food for use during germination, must possess a decided advantage over those reproduced by means of spores.

In the groups of spore-bearing plants ordinarily found fossil, the spores are not known to have developed any particular devices for their wide dissemination, such as flotation in air, attachment to animals, etc. They are produced in vast quantities, and depend upon a few reaching situations favorable for successful germination. Their vitality is also of apparently exceedingly limited duration, and it is doubtful if they could long survive immersion in salt water.

The bearing of the above digression is apparent. Given a fossil flora made up of ferns or fern allies, exclusive of what are known to belong to the cycadofilices, and when such flora is found in two or more separated areas, we are justified, in my opinion, in arguing a practically continuous land connection. They were incapable of crossing very wide reaches of open water, particularly salt water. Fresh-water streams have been to some extent avenues of distribution, but many fossil floras—and living floras as well—are too widely spread to be explained by this means. When, as is usually the case, identical floras occupying different areas are mixed floras, the bearing on the means of reaching the various areas is more complicated. An example may better serve to bring this out. Thus, the Jurassic flora is practically world-wide in its distribution, ranging from Franz Josef Land, 82° N., to Louis Philippe Land, 63° S. It is composed of ferns, fern-allies, cycads and conifers, a large percentage being true ferns. The probability of a close land connection argued on the basis of the true ferns, has already been alluded to. The cycads—the Jurassic is called the age of cycads —were abundant in individuals and numerous in forms. On the basis of our knowledge of living types, it may be stated that cycad seeds germinate immediately on falling from the cone without any necessary resting period. They are not known to retain their vitality for a longer period than three years, and usually but two years. They sink promptly in fresh water and as the stony coat is easily penetrated by water, they either germinate or rot at once. In salt water they will probably sink and decay even more quickly. Therefore, the probability of their being transported for any great distance over open water is reduced to a minimum. The conifers of the Jurassic were reproduced by seeds. They belong to types not known to enjoy any special means for transportation, nor is it probable they could better withstand fresh- or salt-water immersion than the cycads. All classes of vegetation present in the Jurassic, therefore, argue for a practically continuous land connection.

In considering the bearing of any flora on the paleogeographic problem the process is similar to that outlined above. That is, an analysis of the composition of the flora, a study of the means of natural dissemination which includes duration of vitality, and finally a judgment as to its probable means or avenues of transportation, involving a land connection or otherwise.

A word may be said as to the presence of land plants in marine deposits. That the trunks of trees may float for a considerable time and to great distances is undeniably possible, but unfortunately the study of fossil wood has not yet reached that degree of refinement in most cases that will permit of its general use, and reliance in identification must be placed largely in foliar and reproductive organs. The delicate fronds of ferns, leaf-clad branchlets of conifers and the leaves of seed-bearing plants are incapable of long withstanding the immersion and wave action of salt waters. In my judgment, therefore, the presence of fronds, leaves and similar organs in marine deposits argues very near-by land.

The only other point I shall consider is the bearing of plants on the interpretation of *climate*. Since it is generally acknowledged that plants furnish the most reliable data for this phase of the subject, an inquiry as to the kinds of plants that have been found most valuable in this connection may be of interest. Obviously our interpretation of the probable conditions under which the plants of past geological ages grew, must be on a basis of a knowledge of present conditions found to obtain for similar or closely related groups. That we may occasionally err in this is possible, especially if reliance is based on too few forms, but when all the various elements of a flora are considered, the results are thought to be within a close approximation of the truth. Thus, since *Artocarpus*—the bread-fruit tree—only grows at the present day within 20° of the equator, it follows that when *Artocarpus* is found fossil in Greenland, 72° N., the conditions at the time it flourished there must have been tropical or subtropical, and this conclusion is confirmed by the tree ferns and cycads associated with it. Palms can not flourish with a temperature below 40°; a fossil flora, rich in palms of well-defined types, could hardly have grown under very much cooler conditions. Tree-ferns are practically confined to within 30° of the equator and a temperature of approximately 60°. A fossil flora, such, for example, as the Triassic of Virginia, that contains numbers of tree-ferns, must have grown under tropical or subtropical conditions. A fossil flora rich in types, the living representatives of which can withstand a temperature of — 40° to — 60°, or even lower, must have been at least cool-temperate. Cycads are now found only within 30° of the tropics; a rich cycad flora argues then for a tropical or at least a subtropical climate.

Examples of this kind could be multiplied almost indefinitely. In interpreting geological climate selection is made so far as possible of the plants or groups of plants, that are confined at the present day within relatively narrow limits of temperature, be this high, medium or low.

THE CASE OF HARVARD COLLEGE[1]

By Professor J. McKEEN CATTELL
COLUMBIA UNIVERSITY

THE free elective system, three years of college in preparation for the professional school, personal freedom for the student, these are tenets that Harvard has made familiar to us all. But the pendulum now swings backward. It is already decided that the work of the student is to be concentrated and dispersed by faculty decree; that preparatory schools are to be established for freshmen. We are told that the four-year college course should not be shortened, that "every college graduate ought to be equipped to enter any professional school" and that "the professional schools ought to be so ordered that they are adapted to receive him." "College students are amateurs, not professionals"; they should study "a little of everything," and though each should also have "a firm grasp of some subject," it should lie "outside of his vocation." "The college may be regarded as the last period of play."

The scheme on which the president, fellows, overseers and faculty of arts and sciences of Harvard University have united has one merit; they announce that they do not intend to enforce it. Compulsory concentration is useless and compulsory dispersion is bad. Neither good students nor those who do not want to study will be helped. Any such scheme breaks down under the load of its artificiality. The field of knowledge is divided into four divisions for purposes of dispersion, but no faculty can put asunder what God has joined together. According to his interests and needs the student may find his concentration scattered through the four divisions and his dispersion within a single department, as well as the reverse. In my own subject he can find boundless dispersion—witness the fields tilled at Harvard by Professors James, Münsterberg, Royce, Palmer, Santayana and Yerkes—or he can choose a unified and consistent course by innumerable combinations of studies.

Ten years ago a committee from the Harvard department of education made a detailed study of the programs of study of 372 members of the class of 1901. It was concluded that only 7.8 per cent. appeared open to the charge of undue specialization, of whom one third

[1] An address read after the annual dinner of the Harvard Teachers' Association in the Harvard Union on March 12, 1910.

specialized in history and political science preparatory to the study of law. Only 4.5 per cent. seemed to show a lack of proper concentration of energy, and of these one sixth received the A.B. *magna cum laude*. But circumstances alter cases. We are now told that more than half the students concentrate too much or too little. It is said that only one seventh of the students graduating from the law school *cum laude* concentrated too little in college, whereas the medical students did not concentrate nearly so much. It is not likely that medical students are inclined to specialize less than law students. The fact is that Harvard College provides the courses in English, history and political science needed by students of law and does not provide the courses in anatomy, physiology and pathology needed by students of medicine.[2] Instead of requiring students preparing for the medical school to take courses which they do not want, the college should offer the courses which they need.

The free elective system may be a partial failure; but it is doubtful whether, apart from the professional school, a better plan has been devised. The group system is better in so far as it is a professional school within the college; it is no better as a factory for the manufacture of cultivated gentlemen. Sequences and combinations of studies in the college should be planned which give adequate preparation for different kinds of work in life, not only for the orthodox and semi-orthodox professions, but also for business and affairs, and for such special performances as those of the Sanskrit scholar, the psychological expert or the economic entomologist. The courses should be planned by those engaged in these callings, rather than by a college faculty, and they should be elected by the student after proper counsel, rather than forced upon him.

The boy of eighteen or nineteen either should know what he is going to do in life and give at least part of his time to direct preparation, or he should have a working hypothesis. The professions differ in their demands. Medicine and engineering require manual dexterity and much special information; they should be begun in good season. Law and theology are less exacting of special training; a medical or engineering course would not be a bad preparation for the bar or the church, but the converse is not true. A lawyer who becomes a university president may not unnaturally fancy that the preparation suited to a lawyer would also be fit for the physician or engineer. But when he says:

> Many professors of medicine, on the other hand, feel strongly that a student should enter their schools with at least a rudimentary knowledge of those

[2] President Lowell in reply said that the study of Latin is the best preparation for a scientific career, but that the proper preparation for the profession of law is learning to reason. If the lawyer can be taught to reason, there is certainly a valid argument for that much compulsion in college.

sciences, like chemistry, biology and physiology, that are interwoven with medical studies; and they appear to attach greater weight to this than to his natural capacity or general attainments,

one wonders where those professors of medicine are who attach greater weight to rudimentary knowledge of certain sciences than to natural capacity, and whether any one holds that that natural capacity precludes scientific training or conversely.

The special training of a group or professional course is not its only advantage. An expert Sanskrit scholar is better fitted to become an entomologist than an amateur who has studied a little of everything. Any kind of an apperceptive mass—to use the slang of psychology—is better than none at all. The Columbia College faculty in requiring every freshman to take six or seven studies unrelated to one another and largely unrelated to his past or future work prescribes a method which not one member of the faculty would be so foolish as to adopt in his own work. The collective unwisdom of a college faculty is not often exceeded by an undergraduate student. Nor, it may be added, is the skill of a faculty in devising restrictive regulations equal to the ingenuity of the student in dodging them. As Mr. Eliot has recently said, while the word "must" may be heard hereafter more frequently at Cambridge, "I feel a very strong confidence in the ability of the youths that come to Harvard College to take that word with apparent submissiveness, but without allowing it to have any inconvenient effects on the individual."

It is doubtless true that students should not spend four years in electing elementary courses; it is well to persuade them and it may be desirable to compel them to do a certain amount of consistent work in some direction. The problem is largely social rather than educational; it is not serious in the colleges of the great state universities. They have all sorts of programs and curriculums; but as a rule the student does his work because it is of concern to him. He has a major subject; he has already begun, or will take up in a year or two, agriculture, medicine, engineering or some other life work, and in the meanwhile he is preparing for it. The air of the place is saturated with honest work. If these young men and women are crude, it is because their homes are but a generation from the frontier, not because their work in college is real. They not only learn more, but make more progress in polite manners and broadening interests than do the boys in the colleges of the Atlantic seaboard.

Before the section of education of the American Association for the Advancement of Science a year ago, addresses were made by Professor Royce and Professor Tufts on "The American College and Life," which emphasized the need of giving reality to the work of college students by breaking down the artificial barriers between culture

and professional work. Professor Tufts discussed the importance of a "reconstruction of the college ideal of liberal culture . . . by a greater introduction of the vocational element and spirit into college work." Professor Royce said:

> Let us seek to assimilate college work more rather than less to that sort and grade of professional work which calls out a young man's energies just because he feels that in such work something is at stake that is, for him, personally momentous. . . . Let us beware of those theorists who, in the name of what they call the American college, want to sunder afresh what the whole course of our modern American development has wisely tended to join, namely, teaching and investigation, the more technical training and the more general cultivation of our youth, as well as the graduate and the undergraduate types of study. I should abhor the name college if this mere name ever led us into such a backward course as some are now advocating.

Our ideas of culture are inherited, primitive and conventional. There is a hierarchy of those who wear celluloid collars, those with linen collars and those with non-detachable collars. Each class looks down on that below it; but scarcely considers what the wearing of a collar symbolizes. He carries a non-detachable collar who believes that American college students must be forced "to study a little of everything, for if not there is no certainty that they will be broadly cultivated." There are various kinds of culture nowadays—microbes propagating in gelatine, turnips with twenty tons of manure to the acre, and boys at Harvard studying a little of everything.

As a matter of fact, boys at Harvard may be compelled to take all sorts of courses and even to be coached for examinations on them, but they do not of necessity study at all. They react normally to the futility of the scheme. There are many kinds of boys in a college community—grinds and sports, scholars and entrepreneurs. One difficulty is that they divide themselves into social cliques when they ought to mix, and are mixed in the courses when they ought to be grouped with reference to their abilities, interests and future work.

The years from eighteen to twenty-five are precious beyond all measure. A boy of eighteen is the rawest of material; within seven years the pig-iron must become steel and the blade must get its finest edge or it will never cut deep. But we bookmen must remember that words and books and scholarship are not the only things in the world. The pen may be mightier than the sword, but it is feeble beside the workman's tool. An Achilles who has no Homer is not therefore less great. We who talk and write have undue opportunity to exploit our own trade. If we expect others to respect our scholarship, we should in turn honor their performances. The fundamental fault of our whole educational system is that we try to train to superficial scholarship and conventional culture those who should be learning to do their share of the world's work.

The traditions of scholarship attaching to the college are indeed somewhat threadbare. From the monastery, by way of Oxford and Cambridge, came the American college. So long as it was controlled by the clergy for the education of the clergy and the church was a real part of the life of the people, the college was vital, as are to-day the schools of medicine, engineering and law. When intending lawyers and teachers—concerned like the clergymen with words, books and traditions—became a large element among college students the scholastic curriculum was not inept. Six or eight years' study of the elements of the classical languages—scarcely ever reaching so far as reading them with ease or writing them with correctness—did not accomplish so very much in the way of broadening interests and enlarging sympathies, but it gave a good drill and a common stock of knowledge and quotations, which made for the social homogeneity of a class. Poetry and art have so completely based themselves on the classical and biblical traditions that they are in danger of waning together.

Science has in the course of the past century caused a revolution in human life. Its applications have made democracy and universal education possible by enabling one man to do what formerly required ten. Science has created new professions and has at the same time provided the economic conditions which permit large numbers to follow them and to undergo a long period of unproductive apprenticeship. The same economic conditions have permitted the wealthy and potentially idle classes to increase to a vast horde largely lacking the traditions of an aristocracy. The lower death rate due to science is followed by a lower birth rate. Women partly freed from manual work and child-bearing can be idle, go to college or engage in sedentary occupations. Then science has directly reformed our educational system by the new material which it has supplied and by the new method which it has made supreme.

The English and American colleges have but partially and imperfectly adjusted themselves to this new life. The ghost of the obsolescent scholastic system still hovers about the place; it is still haunted by the phantom of the gentleman who hunts over his country estate and drinks two bottles of wine for dinner, but whose son may become a curate or the proconsul of an empire. Oxford and Cambridge have, as a matter of fact, more nearly fitted themselves to the conditions of British society than have our seaboard colleges to American democracy. The B.A. may mean little more than a public-school education and three six-months of residence at the university, but the young men have on the whole a high sense of honor and duty, of traditions to be maintained. In addition to the poll men, there are honor courses at the universities which are strictly special and professional—preparatory to

medicine, law, politics, etc., or giving expert training in subjects such as the biological sciences or the classics. A student may devote three years to exclusive and intensive work in mathematics; and the training has proved excellent, having produced not only many of the ablest mathematicians of the last century, but great men in all departments of activity. The English system of public schools and scholarships selects for the universities a large share of the ablest and most earnest young men of the country; Oxford and Cambridge have continuously sent forth their men to lead the nation. None the less it is true that in numbers, in resources and in educational methods they have remained nearly stationary, while the great movement in higher education in England has been the establishment and growth of the metropolitan and provincial universities. These are essentially trade schools, similar to our own state universities, and having but little in common with our country clubs of the North Atlantic states.

It is not desirable to support at public expense certain country clubs or detention hospitals in which rich boys may be segregated. The idle rich and the lazy poor we have with us always and everywhere. Colleges only contribute their share to the failure to solve a problem at present insoluble. It may be that these rich boys cost society more than they are worth; it may be that their value is a minus quantity. They will, however, occupy a far more important place in society than others. From the vast numbers born in the cottage, there are a few who grasp "the skirts of happy chance" and live to shape a "state's decrees," but in the main those who eat at the high table of the palace are born there or in its dependencies. Thanks to heredity and opportunity combined, there are more dominant personalities, such as Mr. Theodore Roosevelt, Mr. Pierpont Morgan and Mr. Lawrence Lowell, from this small upper class than from the working millions. Whether or not we should be better off without such men is not the question. Until opportunity can be equalized we shall have them; the college must bear its share of responsibility for what they do in the world.

These rich boys are as a rule nice boys and many of them will become leaders in their own class and in the community. The luxury to which they are inured at home does not especially hurt them in college. The difficulty is twofold—they set false standards for the boys who are not rich and they do not themselves profit greatly from their college work and life. The college community is more democratic than any other; but as an institution increases in size sets are formed, and the rich are segregated in dormitories, clubs and fraternities. They enjoy the social life which the idle classes maintain after reaching years of discretion, and are turned in that direction rather than to ideas of useful work and service. They do not see the use of the college courses, but study as little and pay their coaches as much as may be necessary to pass exam-

inations. The president of a large college told me that he could not consider a certain man in connection with the chair of philosophy, because he was said to have leanings toward socialism and there was too much of that kind of thing among the students already. As a matter of fact, this president probably had his eyes on his trustees rather than on his students, and there is altogether too little enthusiasm for ideal ends—wise or foolish—among our college students. On the continent they are the radicals and revolutionaries; here they are too often the premature club men.

A class endowed by the public can only be tolerated if it performs public services. Assuming that the class will last for a time, how can it be taught its responsibilities? Not surely by the Harvard plan of studying a little of everything, but nothing concerned with work in life. Even professional football is better than amateur scholarship. Your true lover is no amateur, but a professional in deadly earnest. Each boy at Harvard, rich or poor, should have some end to which he devotes himself. Those who do not care for scholarship should be given a chance to become interested in business or politics or social affairs, or else the university should be closed to them. But many will become absorbed in scholarly work if given a chance, and this can best be offered by letting them do serious work in some direction and leading them to associate with those already interested in such work.

The plan just now adopted at Harvard of establishing residence halls for freshmen traverses all that I have written. Groups of the most immature students, likely to be classified by the amount they are prepared to pay for rooms and board and the schools from which they come, will be segregated, required to study a little of everything under the supervision of celibate masters, and told that they are entering on a "period of play." If, as is said, "the change from the life of school to that of college is too abrupt at the present day," then let us make the schoolboy more of a man, not the college student less of a man. The groups in college should be formed on a plan exactly the opposite of that proposed, social, local and age distinctions being ignored, and the main grouping being in accordance with the aptitudes and life interests of the students. The ideal is the zoological hall of the old Harvard, where apprentices of a great man and a great teacher lived together. This is told of again in the charming autobiography of Shaler. A boy from the aristocratic southern classes, with ample means and good abilities but no fixed interests, fell into this group. There he discovered his life work and pursued it with boundless enthusiasm. Nor did the fact that he devoted himself exclusively to professional work in natural history in college prevent him from writing Elizabethan plays in his old age. The number of men of distinction given to the world from this small Agassiz group is truly remarkable.

The president of Harvard tells us that the engineering student "labors without a groan on mathematics, which most college undergraduates shun like a pestilence," and most curiously he holds that the engineering student gets no culture from his mathematics, while the college student does, and must by force be exposed to the pestilence he shuns unless he chooses philosophy as the milder disease. If culture is "a little knowledge of everything" and "those things which ordinarily educated men around a dinner table are expected to know"— to quote again—it has little more real significance than the white shirts and black coats of these gentlemen. But surely the intangible trait that we should like to strengthen by our education is almost the reverse of this—something that makes the white shirts and gossip of the dinner table insignificant, seen at times in primitive peoples, in seafaring and farming folk, in hereditary nobles, in scholars—a certain detachment from the here and now and the narrower self, the quality of greatness in a man. This is almost unconcerned with any kind of information, but to a limited degree comes from mastery in one's own field, from historical perspective, from appreciation of the forces of nature.

There are three things that the university would do—represented by the college, the professional schools and the graduate faculty. Through the college it would give men broader interests and wider sympathies, through the professional schools it would teach the routine methods of practise, through the graduate faculty it would improve these methods and enlarge our knowledge. But while the partial separation of these three objects in the university has a historical explanation, it has no real justification. Every child and every man should unite continuously in his education and in his life what the university artificially separates—he should always be doing and learning to do his share of the world's work, he should try continuously to improve the methods of doing it, and he should learn to appreciate the work of others.

In our actual courses we can not do much more than teach efficient methods of routine work. The student can learn to do something in particular, not things in general. Hence our professional schools are on the whole more successful than our colleges or our graduate faculties. Routine research and routine scholarship can be taught in the graduate faculty, which is at present essentially a professional school for university teachers. For original research and productive scholarship we must wait for the man, or possibly search for him, give him a chance and let him alone. But we should welcome him and give him opportunity in whatever department of the university he may be found. The right way to give a man interests that are broad and permanent is not to put him in elementary courses in all sorts of subjects, but to encourage him to learn to do well his work in life and to connect with this by natural associations the larger world in which he may live.

Fortunately no president and no university can confine culture to the college, professional work to the professional school and research work to the graduate school. Each will be found everywhere according to the measure of those who teach and those who learn.

The courses intended to impart "a little knowledge of everything" should, we are informed, be lecture courses by the leading men in the department supplemented by drills from subordinates. In my opinion this is exactly the wrong use of lecture courses. Books and small classes should be used for elementary instruction. Lectures may be needed for special work not to be found in books and are useful as emotional exercises. When used for the latter purpose, the student should not be quizzed or examined on them, but can properly be credited toward his degree for the number of hours he sits in the lecture room.

Futile and somewhat anti-moral is the plan proposed of trying to improve scholarship by persuading students to compete for class rank. We are told that "the free elective system in college has reduced the spirit of competition in scholarship to a minimum," and that "there is a close analogy between outdoor sports and those indoor studies which are pursued for intellectual development, especially in regard to the question of stimulus by competition." As a matter of fact, men pull together in a boat for the glory of their college; the man who plays for his own oar or hand is not esteemed there or elsewhere. There is some excuse for the student's opinion that "C" is the gentleman's grade. To try to make dull and profitless work interesting by competition puts the smell before the automobile.

This does not mean that competition is not a factor of immense importance in life; or that it is out of place in the university. When the best men graduating from the medical school receive the hospital appointments, and the best men in the engineering school find big jobs waiting for them, it is a powerful stimulus to good work. When the first and second wranglers at Cambridge have been assured of fellowships which may be worth $50,000, the attainment has been eagerly sought and highly honored. It should be noted, however, that Cambridge has this year abandoned the ranking in the mathematical tripos, because it was regarded as on the whole injurious to scholarship. If the men who do the best scholarly work in college are properly rewarded for it during their course, on graduation and in after life, their scholarship will be respected even by those who are not scholars.

A proper way to encourage students to do good work is to credit them for the quality of their work as well as for the number of hours of class work which they attend. The Harvard plan of letting the same number of courses be taken either in three or in four years does not accomplish this. The student may do work of the same amount and quality in a year whether he attends ten or thirty hours of class

work. But if the points for the degree are weighted as well as counted, the able student or the diligent student will make more rapid progress. If he can do in two or three years the work for which the poorer student requires four years, there is no reason why he should not go forward to the professional or graduate school. It would also be just and a proper stimulus to let good students pay lower and poor students higher fees in proportion to the quality of their work. The good students who profit themselves and contribute to a better spirit in the institution should receive a larger part of the subsidy contributed for college education, while the students who learn but little and may be a public nuisance should not be supported at college at public expense.

But the best reward for scholarly work is adequate recognition of the work as preparation for a career in life. At Columbia University a man takes his doctor's degree at the average age of 27 years. He is fortunate if he receives immediately an instructorship at $1,000 a year; the increments of salary are $100 a year for ten years, so that at the age of 37 he receives a salary of $2,000. In a commercial community the imagination is not stirred by such figures. The university is a parasite on the scholarly impulse instead of a stimulus to it.

The first need of our universities and colleges is great men for teachers. In order that the best men may be drawn to the academic career, it must be attractive and honorable. The professorship was inherited by us as a high office which is now being lowered. Professors and scholars are not sufficiently free or sufficiently well paid, so there is a lack of men who deserve to be highly rewarded, and we are in danger of sliding down the lines of a vicious spiral, until we reach the stage where the professor and his scholarship are not respected because they are not respectable.

I should myself prefer to see the salaries, earnings and conveyings of others cut down rather than to have the salaries of professors greatly increased. When a criminal lawyer—to use the more inclusive term for corporation lawyer—receives a single fee of $800,000, our civilization is obviously complicated. Every professor who is as able as this lawyer and who does work more important for society can not be paid a million dollars a year. But neither is it necessary to pay him so little that he can not do his work or educate his children. I recently excused myself somewhat awkwardly for not greeting promptly the wife of a colleague by saying that men could not be expected to recognize women because they changed their frocks. She replied: "The wives of professors don't." It is better to have wit than frocks; but in the long run they are likely to be found together.

The first step of a really great university president would be to refuse to accept a larger salary than is paid to the professors. The second step would be to make himself responsible to the faculty in-

stead of holding each professor responsible to him. The bureaucratic or department-store system of university control is the disease which is now serious and may become fatal. This subjection of the individual to the machinery of administration and to the rack wage, is but an invasion of the university by methods in business and in politics from which the whole country suffers. We may hope that it is only a temporary incident in the growth of material complexity beyond the powers of moral and intellectual control, and that man may soon regain his seat in the saddle. Certainly Harvard has led the way. It has adopted a scale of salaries independent of superficial supply and demand, and has placed them outside the influence of intrigue and favoritism. The bureaucratic system is less dominant than elsewhere. And it has its reward; for I find in an objective study of the distribution of the scientific men of the country that no less than one fifth of those most eminent are here.

It has been said more than once that the college is in danger of being crushed between the upper millstone of the professional school and the nether millstone of the secondary school; those who have used this simile do not appear to realize that this is the way fine flour is made. The trouble with our educational system is that the college has not only exploited its frivolous amateurism and its futile scholasticism at home, but it has imposed them on the high school and even on the grades. When we have high schools fit for the people and professional schools of the right sort, the college will be molded into proper shape.

President Lowell closed his inaugural address with the words:

> It is said that if the temperature of the ocean were raised, the water would expand until the floods covered the dry land; and if we can increase the intellectual ambition of college students, the whole face of the country will be changed. When the young men shall see visions the dreams of old men will come true.

If the temperature of the ocean were raised sufficiently, Cambridge and its university would be submerged, while the great continent with its state universities would stand untouched. But if the intellectual ambition is sound and the visions are sane Harvard College can be saved.

I trust that I have not exceeded the privileges proper to a guest or the freedom allowed by an after-dinner address. Those men and those institutions which are too great for compliment are still subject to honest criticism. It would be impertinent for me to praise Harvard University and its leaders. Harvard stands apart from and above all our other universities, secure in its past and in its future, one of the great contributions made by America to the civilization of the world.

THE PROGRESS OF SCIENCE

THE SALARIES OF PROFESSORS

At the eleventh annual conference of the Association of American Universities Professor G. H. Marx, of Stanford University, presented an elaborate study of the problem of the assistant professor. It appears that assistant professors in the leading universities are of an average age of thirty-seven years, and have an average salary of $1,800. Four fifths of them supplement their salaries from outside sources and many are in debt. They have on the average one child. There seems to be considerable difference in the status of the assistant professor in different universities. In some institutions they have nearly the same influence as the full professor in faculty legislation and departmental control, while in others they state that they are practically ignored. The larger salaries paid to professors are about the same at Harvard and Columbia, but at Harvard the minimum salary of the assistant professor has recently been increased to $2,500, while at Columbia it has been placed at $1,600.

The higher cost of living and the cost of higher living combined—the increase in the price of the necessities of life and the more exacting standards of comfort—bear heavily on those having fixed wages, and perhaps university professors suffer more than any other class. Railway employees can threaten a strike; they are paid more, and rates for passengers and freight are increased, not to the advantage of the professor. Even the clergyman and his congregation can adjust matters. But the university has an income which does not increase automatically, and the larger the number of students the poorer does it become. With the best of will the administration can not obtain an adequate number of teachers and pay them adequate salaries. In the course of the last ten years salaries have remained stationary, while the cost of living has increased fifty per cent. and the standards of living have probably increased in an equal degree. The effective salary of the professor is only about half what it was ten years ago.

While professors are underpaid in comparison with successful men of business or leaders in the other professions, it is not certain that this is the case in comparison with the great mass of their fellow citizens. They are the least privileged members of the privileged classes. There is but little abstract justice in the rewards which the world gives. People get what they can, and what they can get depends on extremely complicated conditions. Lord Kelvin received several million dollars for his inventions and engineering advice, a modest salary as a university professor and nothing at all for his great contributions to mathematical physics. Probably his services to society were the most in the work for which he was not paid and the least in the work for which he was paid the most. But even in the latter case he produced far more wealth than he received. In like manner Mr. Alexander Agassiz earned several million dollars as the result of three or four years devoted to mining, but paid large sums to carry on his scientific work which is of such high value to society.

Society has no way of paying men such as Faraday or Darwin for their immense services. The competitive system applies to teaching, but not to original research and productive scholarship. The importance of teaching,

however, as compared with other professions, is now underestimated. The rich man who employs a lawyer and a physician who charge at the rate of $50,000 a year, regards a thousand dollar a year teacher as good enough for his children. The teacher is not as a rule underpaid, but is a man of inferior ability and character.

The difficulty in the case of the relatively small salaries paid to assistant professors and professors is not so much that they are underpaid, as that universities and colleges are satisfied with men who are worth so little. It is, however, true that these institutions depend on the dignity and prestige of the position to attract men, and use this motive in place of salary. The result of this policy, however, is to lower the prestige of the position, so that it can not permanently be used in this way.

But while we may depend on the competitive system to adjust the salaries of teachers and only try to increase in the community the appreciation of the importance of having able and well-trained men, there still remains the problem of how we are to encourage and pay for original research and productive scholarship. These are in the main a by-product of the work of the teacher and are not paid for directly. Institutions want the credit of having men of scientific distinction and men value the honor which follows scientific achievement. But these motives are not sufficient, and become less so as the total number of scientific men increases. While the average salary paid to teachers may be about the same as in the other professions, the leaders do not receive salaries commensurate with the incomes of the leading lawyers, physicians, journalists or even clergymen. Under existing conditions it is probably desirable that they should receive larger rewards in order that society may have the ablest men in its direct service and may give them the strongest motives to do their best work. It is certainly little less than a scandal that the effective salaries of university professors should have been greatly reduced in the course of the past ten years.

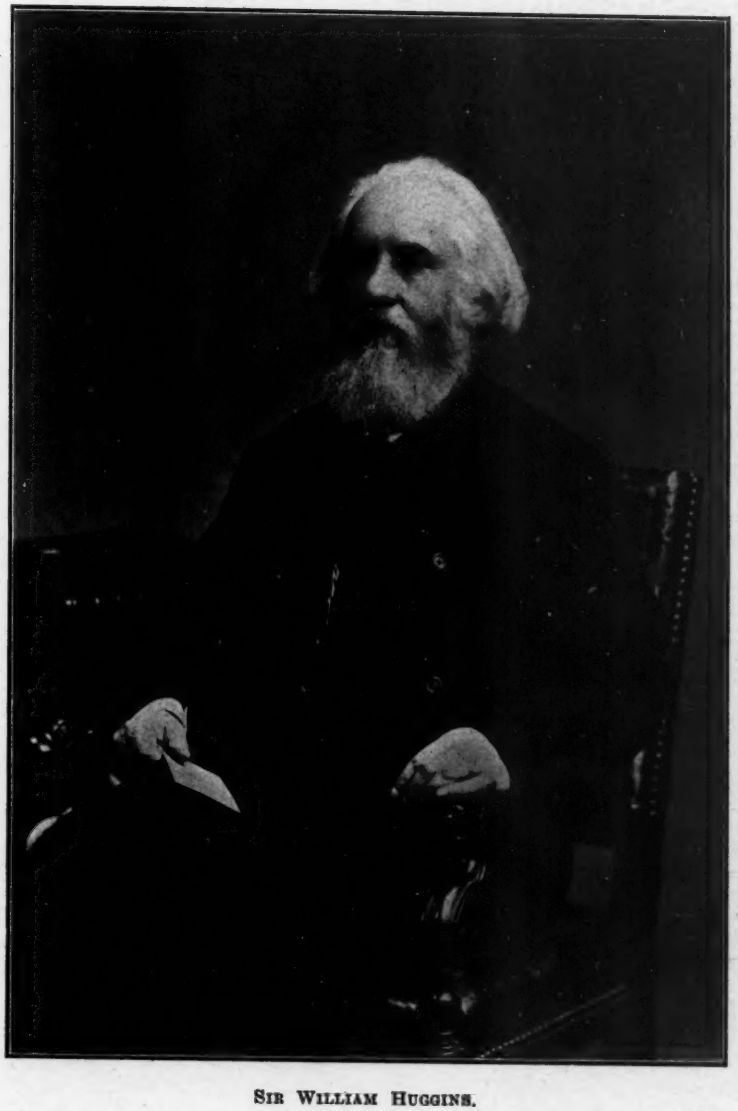
SIR WILLIAM HUGGINS

DEATH has taken one more of the great men who gave distinction to the Victorian era. Hooker, Wallace, Lister and Galton are left, but the period is now closing which gave Great Britain such distinction in science as has seldom been equaled in any field or in any country. It is indeed possible that the science of Great Britain in the nineteenth century is the greatest achievement of our race.

Huggins was born in London in 1824. He was privately educated, and held no university or other position, but with ample means erected for himself in 1856 an observatory at Tulse Hill. He took the lead in applying the spectroscope to astronomy and may be regarded as the founder of the science of astrophysics. In his work he had the constant assistance of Lady Huggins. He was president of the Royal Society and one of the five scientific members of the order of merit. We hope to give in some subsequent issue an appreciation of his great contributions to science.

LORD KELVIN

AN adequate life of William Thomson, Baron Kelvin of Largs, has been written by Professor Silvanus P. Thompson and published by Macmillan and Co. Although an editorial note on Lord Kelvin's life and work was published in a recent issue of the MONTHLY (November, 1909), too much honor can not be paid to one of the greatest geniuses of the nineteeth century. We reproduce two from the many interesting portraits which are included in the volumes and Professor Thompson's final paragraph. After describing the funeral in Westminster Abbey, he writes: "For once, in the



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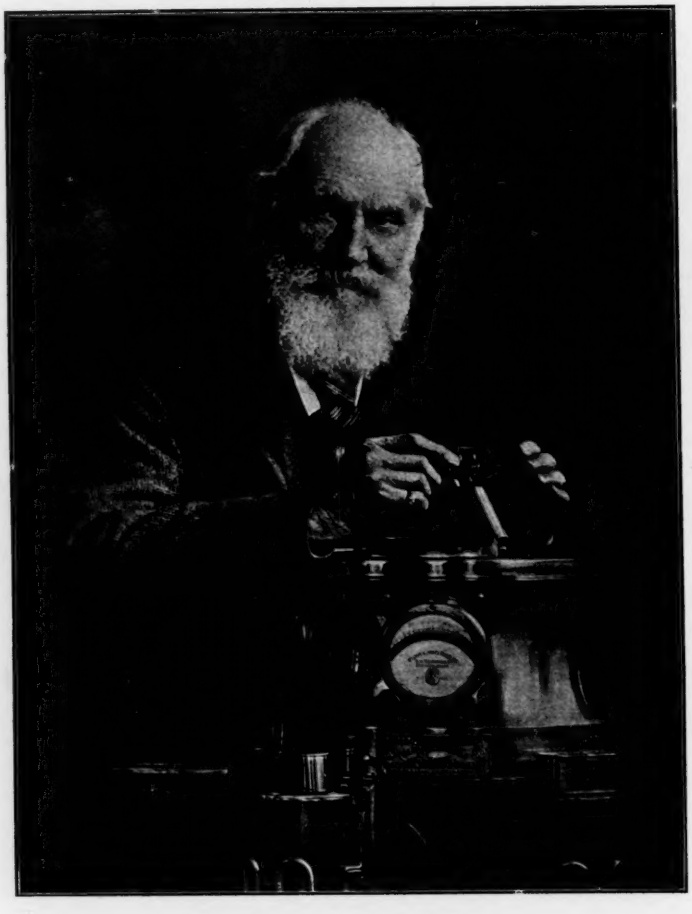
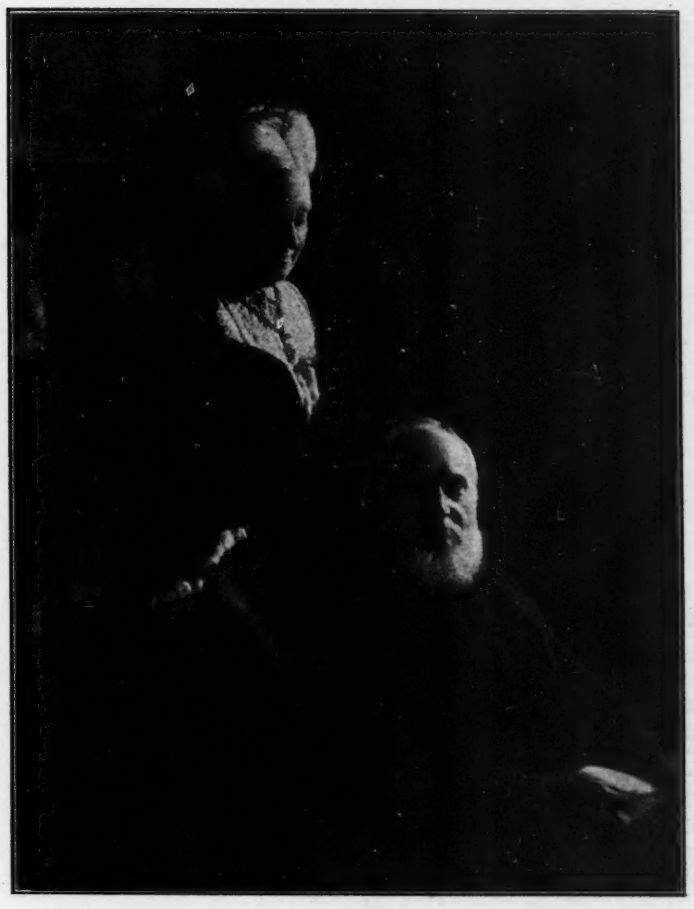


LORD KELVIN WITH HIS COMPASS.

universal tribute rendered to the memory of Lord Kelvin, there seemed to be some revival of recognition of what the nation owes to science and to her great men. That which impressed Voltaire nearly two hundred years ago at the funeral of Newton was the public recognition which the England of that day accorded to the great representative of science. To-day the man of action looms larger in the world than the man of thought; and mankind which worships success is apt to heed little the thought and toil without which success is not achieved. In an age which has been preeminent over all that ever went before for the advances of science, the fashion of glorifying the warrior and the orator seems a grotesque anachronism. Mr. Gladstone's dictum, 'that the present is by no means an age abounding in minds of the first order,' did but reveal that he too shared the general blindness. The fact is that there never was an age so rich in minds of the first order in science. The nineteenth century has, intellectually, been the golden age, not of drama or of adventure, but of science. It has been an epoch distinguished by a galaxy of men who made it great, and who, whether the world recognizes it or not, were great men. Though Lord Kelvin was not the last of these, he was assuredly the greatest; and his name will be revered and



LORD AND LADY KELVIN IN 1906.

his memory cherished long after those who sat at his feet and listened to his voice shall have passed away. His words, his thoughts remain. And not his thoughts only; for though he was essentially a man of thought, he was also a man of effort to whom came the high privilege of achievement. That laborious humility for which he was conspicuous, that unceasing activity which drove him, as by an internal fire, from success to success, mark him as a man of purpose. In an age that threatens, now to fester into luxury, now to swell into the degenerate lust of bigness, now to drivel into sport, such a strenuous career as his, and such high ideals of intellectual endeavor as illuminated his whole life, are possessions not lightly to be lost."

SCIENTIFIC ITEMS

WE record with regret the deaths of Dr. H. T. Ricketts, of the University of Chicago, who had been in Mexico conducting research on typhus fever and died from that disease; of Dr. Eugene Hodenpyl, the pathologist, of New York City; of Professor William Graham Sumner, of Yale University, eminent for his contributions to sociology and economics, and of Sir Robert Giffen, the British statistician.

MEMBERS of the National Academy of Sciences have been elected as follows: Forest Ray Moulton, assistant

professor of astronomy in the University of Chicago; William Albert Noyes, professor of chemistry in the University of Illinois; Thomas Burr Osborne, research chemist in the Connecticut Agricultural Experiment Station; Charles Schuchert, professor of paleontology in Yale University; Douglas Houghton Campbell, professor of botany in Stanford University; Jacques Loeb, professor of physiology in the University of California, who will become head of a department in the Rockefeller Institute for Medical Research, and John Dewey, professor of philosophy in Columbia University.

SIR WILLIAM RAMSAY will be president of the British Association for the meeting to be held next year at Portsmouth.—Dr. John Trowbridge, who retires this year from the active duties of his chair at Harvard University, has been appointed honorary director of the Jefferson Physical Laboratory. Dr. Abraham Jacobi, emeritus professor of the diseases of children in the College of Physicians and Surgeons of Columbia University, celebrated his eightieth birthday on May 6. On April 23, exercises were held at the Mount Sinai Hospital in his honor. A bronze bust was presented to the hospital by the medical and surgical staff, and a new library named in his honor was given by the board of directors. At a dinner given the same evening by the trustees of the German Hospital announcement was made that the new children's ward which Mrs. Anna Woerishoffer has given to the hospital will be known as "The Dr. Abraham Jacobi Division for Children."

THE will of Alexander Agassiz, dated September 17, 1906, was filed at Newport, on April 14. He bequeathed $200,000 to Harvard University, half for the Museum of Comparative Zoology and half for its publications. The university also receives scientific apparatus and books, and will ultimately receive the further sum of $12,000. Mr. Agassiz further bequeathed $50,000 to the National Academy of Sciences and an equal sum to the American Academy of Arts and Sciences. $25,000 is left to the Newport School of Manual Training, to which ultimately $6,000 will be added. Mr. Agassiz's will further provides that in the case of the death of any one of his three sons without issue his share of the estate shall ultimately go to Harvard University for the Museum of Comparative Zoology.

MORE than $2,000,000 has been contributed to Washington University, St. Louis, for the medical department. The donors are Messrs. William K. Bixby, Adolphus Busch, Edward Mallinckrodt and Robert S. Brookings. Added to this are the resources of Barnes University, recently absorbed; the Martha Parsons Hospital and the original endowment fund of the university. New appointments have been announced as follows: Dr. George Dock, of Tulane University; Dr. John Howland, of the University and Bellevue Hospital Medical College; Dr. Eugene L. Opie, of the Rockefeller Institute for Medical Research, and Dr. Joseph Erlanger, of the University of Wisconsin. Construction of new buildings, to cost more than $1,000,000, will begin at once.

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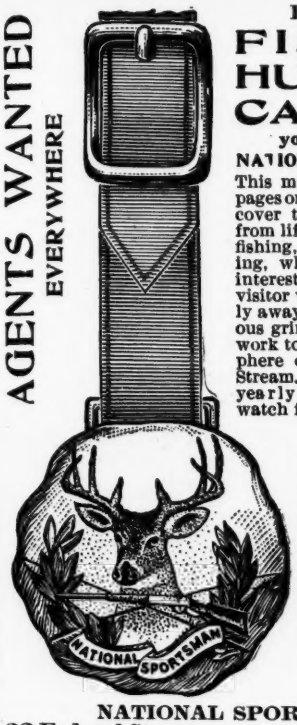

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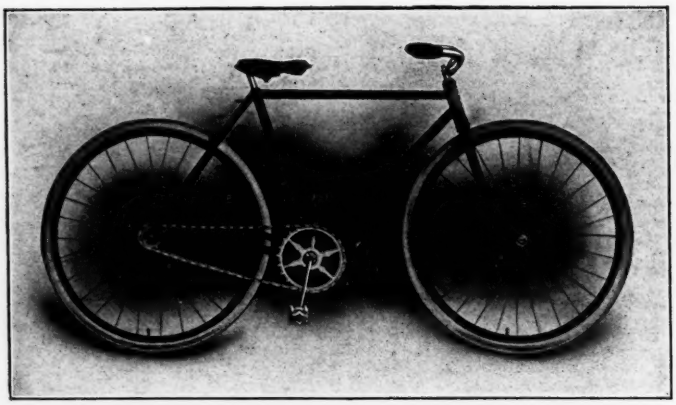

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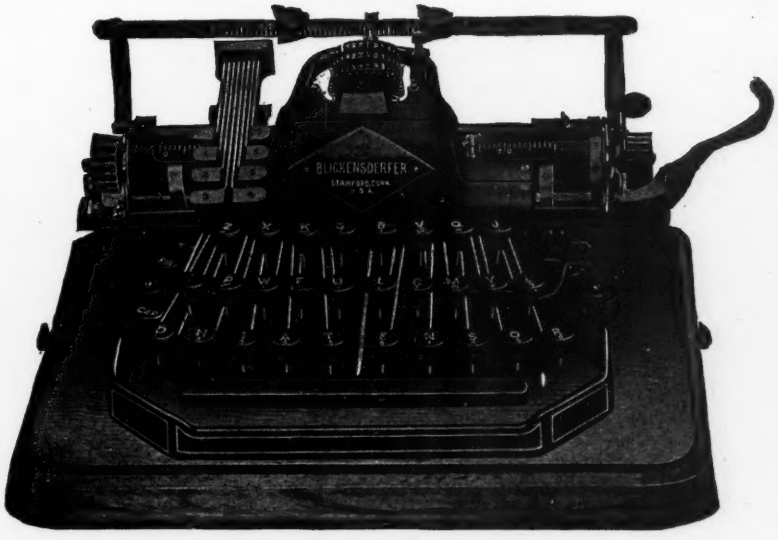

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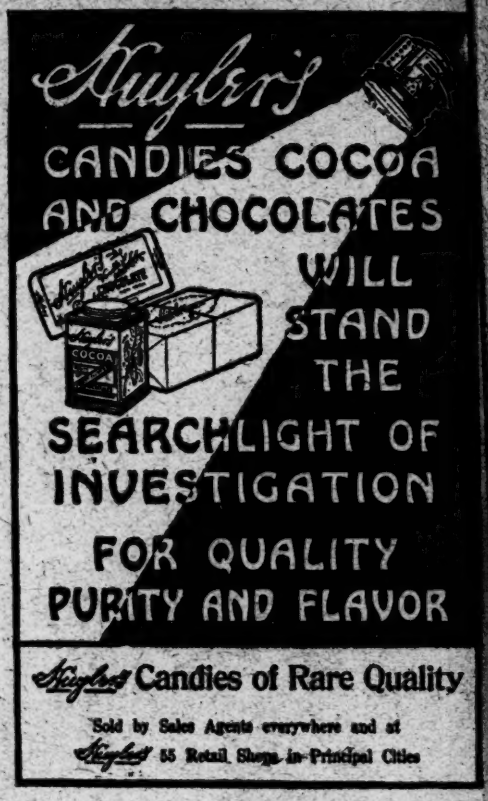

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